PB-227 926

BASIC RESEARCH ON SULFIDE OCCURRENCE AND CONTROL IN SEWAGE COLLECTION SYSTEMS

Los Angeles County Sanitation District

Prepared for:

Federal Water Pollution Control Administration

28 February 1969

DISTRIBUTED BY:

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PB 227 926

BASIC RESEARCH ON SULFIDE OCCURRENCE AND CONTROL IN SEWAGE COLLECTION SYSTEMS

Summary Progress Report
March 1, 1968 - February 28, 1969

County Sanitation Districts of Los Angeles County
John D. Parkhurst, Chief Engineer and
General Manager - Project Director

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Research and Development Grant 11010 ENX
U.S. Department of the Interior
Federal Water Pollution Control Administration

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INTRODUCTION

Sulfide in sewage and hydrogen sulfide escaping from sewage into the atmosphere cause odors, damage to structures, and loss of life. Sulfide problems are serious, yet relatively little research has been done on some of the basic features of sulfide generation. Of many possible methods of sulfide control, only one or two have been studied adequately. An engineer does not have any firm basis to choose a control procedure, or to predict results and operating costs. The sulfide problem is getting worse due to lower infiltration rates, higher sewage temperatures, longer sewer systems with flatter grades and separate systems replacing combined. The seriousness of the sulfide problem demands an expanded knowledge of the occurrence and control of sulfide in sewage collection systems.

It is the purpose of this project to meet the need stated above and to provide the expanded knowledge needed to cope more adequately with the problem.

The scope of work for this study is as follows:

1. To investigate and define the inter-relationship of the basic parameters governing the occurrence of sulfide in a sewage collection system.

2. To investigate corrosion of concrete pipe, defining the factors involved and the rate of corrosion.

3. To investigate the effectiveness of various methods of treatment to control sulfide generation, hydrogen sulfide evolution and concrete corrosion and to present an economic comparison of the various treatment methods.

The project is supported in part by a U.S. Department of the Interior, Research and Development Grant 11010 ENX, Federal Water Pollution Control Administration. This report covers the first year of a three-year study.

SUMMARY STATEMENT OF PROGRESS

March 1, 1968 to February 28, 1969

GENERAL

The early months of the first project year (March through June 1968) were occupied mainly with preliminary tasks required to train and organize staff and to assemble and construct equipment required for the work, and with the development of a detailed research plan for the project.

Some of the specific tasks accomplished during this period were:

1. Hiring and training of personnel.

2. Design and construction of an office-laboratory building in Compton to provide a base of operations.

3. Specifying, purchasing and equipping vehicles and the laboratory for the project.

4. Designing and construction of specialized equipment such as air control assemblies for force main tests, activated charcoal filters for odor control at force mains, Palmer Bowlus slab flumes for sewers from 10" to 27" in diameter.

5. Development of the research plan which includes detailed field test procedures, criteria for selection of test sites, guidelines for non-routine laboratory research.

   The 23 page Research Plan that was developed in final form in May 1968 continues to be the basis for work on the project. A few significant changes have been necessary as insights have developed and revision of the timetable is indicated, but the plan continues to be a sound working document.

6. Selection of suitable sites within the Districts' system for various types of tests.

Beginning in July 1968 and continuing to the present time the main activity has been the gathering of field data. A review of this data gathering, classified by type of site, is shown below.

GRAVITY SEWER

Thirty three sites were originally selected. Useful data have been obtained at twenty and further tests are planned on these sites as well as other sites not yet tested.

Tests are made of changes of oxygen and sulfide concentrations between two manholes with and without the addition of chemicals.

The chemicals added include:

1. Sodium sulfides added to provide sufficient sulfide to measure the rates at which it is oxidized. This is necessary in the winter when little sulfide is produced.

2. Zinc sulfate. Experimenting with this salt provides a better understanding of its use as a sulfide control measure, and at the same time allows a determination of the rate of sulfide production by the slime layers, uninfluenced by oxidation.

3. Sodium hypochlorite. This disinfecting agent is added to a sewer that has first been cleaned, in sufficient amount to virtually stop all biological action, allowing measurement of the rate that oxygen is absorbed at the surface of the stream.

4. Other chemicals as required for special purposes.

Oxygen absorption is an important factor, since the prevention of sulfide buildup in gravity sewers depends upon an adequate rate of oxygen supply through the air-water interface. This is the first time that oxygen uptake in a sewer has been measured. The rates are relatively low in comparison with fresh water. Would it be feasible, as some have suggested, to increase oxygen uptake by mechanical means, or by adding pure oxygen to the sewer atmosphere? The studies now being made will be an important aid in working out answers to these questions.

A total of some 91 usable runs have been made. The results of these runs are tabulated on summary data sheets, copies of which are attached to this report.

The data are currently being analysed. It would be premature to state any conclusions. It is clear, however, that some of the most complete and reliable data ever gathered on conditions

related to sulfide buildup is being obtained. Oxygen plays a significant role in sulfide generation and buildup. Because some fairly recently developed tools are available, extensive information on this role is being gathered for the first time. When that role can be defined with some clarity it may result in new insight into the problems of sulfide prediction and control.

FORCE MAIN SITES

Initially, nine force main sites were selected for study. To date, data has been gathered at three of those original sites and one additional. Excellent data are being accumulated on:

a. Sulfide generation

b. Rate of oxygen absorption from injected air

c. Amount of air entrained in the force main at various injection rates.

d. Oxygen depletion in injected air as related to sewage strength, injection rates, temperature and other factors.

There has not, up to this time, been any reliable way to estimate the amount of air required when designing a compressor installation for a force main. We now have determined the requirement for one such main. By exploring the basic factors of oxygen absorption from the injected air and the rates of oxygen utilization, it will be possible to develop a rational calculation for the amount of air needed. It may be said that the experiments made thus far indicate that the dissolving of air in a force main is exceptionally efficient from the power standpoint in comparison with the usual methods of aerating water.

In this study significant data are being gathered and are currently being analysed. More data are needed before any conclusions can be reached, but there is no doubt that useful design criteria will result from studies.

CORROSION-EVOLUTION SITE

Considerable difficulty was experienced in finding a suitable site for correlation of sulfide content of the sewage and the sewer atmosphere with rates of corrosion of concrete. Preliminary tests were run on three sites but problems developed each time which eventually led to abandonment of the proposed site.

A firm selection of such a site has now been made on the Plaza Trunk in Palos Verdes. A construction permit has been obtained and the required installations are designed and scheduled for construction early in March 1969.

SIPHON SITES

Nine siphon sites were originally selected. Initial generation tests have been made on four sites to date. The field crew is currently working at siphon sites, and will complete a first round on all sites in the immediate future. Generation tests will then be re-run during the summer when temperatures are higher.

LABORATORY WORK

Laboratory research has proceeded along the lines originally outlined in the research plan with mixed results. Initial tests with the laboratory filled pipe test apparatus showed that for some, as yet undefined, reason the filled pipe did not generate sulfide as rapidly as force mains in the field. These results and those of some initial runs with various nutrients led us to explore the nutrient problem through a series of laboratory, filled-bottle tests. These bottle tests have given some unexpected results. Certain nutrients that increase the BOD when added to sewage, and that were expected to increase sulfide generation, did not in fact do so. Nothing else has yet been found that equals sewage as a sulfide generating medium. The work both with filled bottles and with the filled pipe apparatus is continuing in an effort to resolve the anomalies encountered.

Work was also done early in the year on the ionization constant of hydrogen sulfide. The values for this constant previously published are known to be inaccurate and better values will be needed later in this project when data from the corrosion-evolution site are analysed. This is nearing completion.

Considerable work has been done on developing a laboratory or field test for sulfur compounds in intermediate stages of oxidation between sulfate and hydrogen sulfide. It is believed that the presence or absence of such intermediate sulfur compounds may have a major effect on the sulfide buildup potential in the sewer. The work on the test for "reducible sulfur" is well along but not yet completed. Some initial field use of the test should be possible beginning in March.

NEXT STEPS

About a third to a half of this first project year was occupied with preliminary tasks of planning, assembling equipment, training personnel and refining techniques. It is to be expected that the next year will be markedly more fruitful in gathering of reliable relevant data.

It seems clear that this data gathering period ought to extend through the high temperature summer period of 1970 in order to get enough information for reliable conclusions.

Active analysis and collation of the field data have begun. This will continue and will occupy more time through the remainder of the project than heretofore. It appears though that preparation of a final report could be undertaken most expeditiously after the conclusion of a field data gathering period. This suggests a report preparation period beginning about December 1970.

PROJECT ORGANIZATION

PERSONNEL

The project is under the direct supervision of Mr. Jack Livingston, Project Engineer. The three-man field crew from March to December, 1968, consisted of William Parsonson, Richard Boyington, and Jon Boss. In December, 1968, Mr. Parsonson transferred off the project, and in January, 1969, Mr. Glen Schnoor was hired. The field crew was placed under the supervision of Mr. Boyington in December of 1968.

The consulting firm of Pomeroy, Johnston and Bailey, Civil and Chemical Engineers, provides technical services under a purchase order issued by the Sanitation Districts. Dr. Richard Pomeroy worked as needed about three days per month during the year. Mr. Harry Bailey worked about three days per week on the project. Over-all supervision is provided by Mr. Charles Carry, Division Engineer for Research and Development for the Sanitation Districts.

Mr. John D. Parkhurst, Chief Engineer and General Manager of the Sanitation Districts, is Project Director. Regular staff meetings were held about monthly and were attended by Messrs. Livingston, Pomeroy, Bailey, Carry, and Mr. Frank Dryden, Deputy Assistant Chief Engineer, who is responsible for all field sewerage activities of the Sanitation Districts. Mr. Parsonson attended some of the staff meetings during an initial organization period.

HOUSING AND EQUIPMENT

A combination office and laboratory building approximately 16' x 36' was built for the project at the Compton maintenance field office site of the Sanitation Districts.

This building provides office space and a laboratory that is equipped to carry out the most routine of the laboratory tests required by the project. Mr. Rodney Abercrombie is employed part time for this purpose, and has been trained to do the work required.

For field work the project has a Ranchero pickup truck and a Chevrolet Sports van. Both vehicles have been specially equipped to facilitate the work of the project.

Considerable time was spent by project personnel during this first year of the project in constructing special equipment to assist the work. Some items such as air control assemblies, odor control filters, and Palmer-Fowlus slab flume inserts are described in the technical discussion in appropriate sections of this report.

RESEARCH PLAN

A detailed research plan was developed and revised in the early months of the project. That plan is still generally valid and is being utilized as the project proceeds. A copy of this plan is attached as an Appendix.

That Research Plan called for work in five principal areas:

1. Evaluation of factors affecting hydrogen sulfide generation and oxidation in free-flowing gravity sewers.

2. Correlation of sulfide incidence, and turbulence with corrosion in sewer atmospheres and with sulfide evolution rate.

3. Evaluation of factors affecting sulfide generation in filled pipes.

4. Comparision and evaluation of treatment methods for sulfide control.

5. Evaluation of effect of upstream discharge of waste sewage sludge on sulfide buildup.

During this first project year, significant field data have been gathered in relation to two of these areas, i.e., gravity sewers and filled pipes. In addition, data have been gathered on one particular treatment method: air injection in force mains.

Some detailed planning was undertaken with respect to other treatment methods but field testing was deferred to summer because of the sharply decreased sulfide buildup in sewers in the low temperature winter months.

Considerable preliminary planning and field testing has gone into the selection of a suitable evolution-corrosion site for the work. The special test installations have been designed and are expected to be constructed in March 1969. Data gathering should begin there soon thereafter.

LABORATORY AND FIELD TEST PROCEDURES

FLOW MEASUREMENT

Some importance attaches to the measurement of flow rate in the sulfide buildup tests in gravity sewers. Generally, sewers are being tested over a very wide range of sizes; consequently it is not practical to utilize the same flow rate measurement method throughout. Testing is being undertaken in sizes ranging from 10 inches to 60 inches in diameter.

Generally no serious problems have been encountered for sizes 27" and smaller, since Palmer-Bowlus slab flume inserts are of a practical size to handle in these pipe sizes, and the use of these flumes is preferable wherever possible because of their proven accuracy.

For pipe sizes larger than 27" diameter, it is necessary to measure the flow by two or more separate methods and then make a judicious selection of the method that is most practicable in each particular case. The methods that have been utilized are as follows:

The area-velocity method ($Q=AV$) is simplest to use and is used by preference wherever there is reason to believe that it is accurate. It is known from field experience that the measurement of water depth is often influenced by field conditions to such an extent that measurements of the same flow at different manholes

will be widely variable, introducing much uncertainty. Velocity is measured by use of fluorescein dye and is subject to some difficulty in certain circumstances, such as in a very deep sewer or in a sewer carrying highly colored waste.

Generally the area-velocity method has been checked by another method, and if agreement is reasonably close (5%) the Q=AV method is used. Other methods that have been used for spot checks are the "single dose dilution method" using a concentrated salt solution, or the total count method using a radioactive tracer. These last two methods are the same in principle, differing in the additive used and in the method of its detection.

IDENTIFICATION OF TEST PROCEDURES

It was necessary early in the project to settle on test procedures for all tests and measurements to be made. This was done insofar as tests could be anticipated. Modifications and enlargements of the list will undoubtedly be made as experience indicates that changes are needed.

WORK PERFORMED

March 1, 1968 - February 28, 1969

During the twelve-month period, major progress was made on the research project. Early months were occupied mainly with design purchase and construction of needed equipment and housing, and with development of a detailed research plan. Beginning in July, 1968, the gathering of field data was undertaken. Most initial testing centered on sulfide buildup sites and force main sites but some data were gathered at other sites and on related questions.

Reference to Figure 1 will give some idea of the distribution of work effort throughout the year.

TABLE I

TESTS AND MEASUREMENTS TO BE MADE

Test or Measurement	Method	Place to be Made
Sulfides in Sewage, Total and Dissolved	Pomeroy	Field
Sulfides in Atmosphere	Pomeroy	Field
pH	pH meter	Field
Temperature	Thermometer	Field
Dissolved Oxygen	D. O. Meter	Field
Dissolved Oxygen	Winkler	Field & Compton Lab (occasional only)
Biochemical Oxygen Demand (1-day and 5-day)	Dilution method	Compton Lab
Biochemical Oxygen Demand (1-day and 5-day)	Warburg	PJB, Pasadena (occasional)
Chemical Oxygen Demand	Dichromate method	PJB, Pasadena
Chloride (in salt tests)	Mercuric nitrate method	Compton Lab
Velocity	Fluorescein dye method	Field
Water Depth	Tape measurement from reference point	Field
Atmospheric Oxygen	Beckman Oxygen Analyser or Orsat	Field
Flow Rate	10", 18", and 27" pipe, Palmer-Bowlus Slab Flume	Field
Flow Rate	36", 48", and 60" pipe, Q=AV or radioactive gold or salt dilution test	Field

Figure 1

LACSD Sulfide Research

General Schedule of Work Performed -- March 1, 1968, to February 28, 1969

General Schedule of Work Performed
March 1, 1968, to February 28, 1969

Month	Personnel	Review & Evaluation Prior Work	Preparation of Res. Plan	Vehicles	Housing and Laboratory	Filled Pipe Assembly	Bottle Tests of Nutrients	Gravity Buildup Sites	Force Main Sites	Siphon Sites	Corrosion Test Site	Treatment Methods Tests	Miscellaneous Laboratory Investigations
1968													
March	Hiring and training of personnel: Livingston, Parsonson, Boss, and Boyington	X	X	Prep. specs		Design Equipment		Selection of Sites	Design Equipment				To sharpen and smooth out test procedures
April		Completed	X	Ordered									
May			Revision		Construction	Installed		Inspection	Site Selection	Site Selection and Inspection			
June						Tests in Progress			Odor Problems at Bluff Cove, Hollywood Riviera, Long Point, and Marineland		Design & Selection Preliminary Testing to Determine Suitability of Proposed Sites		
July				Arrived 7/15	Equipment on Order			Field Tests at 25 Sites					
August				Install Equipment									
September				Functioning	Plumbing Installed		Work Begun						
October													
November					Routine tests being done at Compton								
December	Parsonson transferred												
1969													
January	Schnoor hired								Lunada Bay		Construction	Detailed planning work deferred until summer	
February										Tests Begun at 9 Sites			

Figure 1

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SULFIDE GENERATION AND CONTROL IN GRAVITY SEWER

GENERAL

Work has been either undertaken or planned on three types of sites on gravity sewers. These are:

Gravity Sewer Site

This is a section of sewer with uniform grade and size which flows partly full at all times.

Siphon Site

This is a section of sewer that is depressed below a uniform grade between its ends such that the pipe is completely filled at all times.

Evolution-Corrosion Site

This is a section of sewer that flows partly full and has dissolved sulfide present in the flow at all times.

The mechanisms of sulfide generation and destruction in a sewer are at least partially understood. The main processes that are recognized are as follows:

Sulfide Generation - refers to the generation of H_2S by anaerobic bacteria present in the sewer.

Sulfide Oxidation - refers to the chemical oxidation of sulfide ion in sewage to sulfate or other sulfur compounds. Oxidation may be due to reaction with dissolved oxygen or other oxidizing agents in the sewage.

Sulfide Evolution - is the loss of H_2S to the atomosphere over a sulfide bearing sewage surface.

Sulfide Buildup is what occurs when the sulfide content of the sewage increases within a test reach of sewer. If the sulfide content lessens within the test reach the result is referred to as Sulfide Depletion. Depletion is of course the same as a negative buildup.

In many sewers, the three processes of generation, oxidation and evolution are going on continuously. When sulfide generation exceeds the combined losses due to oxidation and evolution then a sulfide buildup occurs. Conversely when oxidation plus evolution exceeds sulfide generation then no buildup occurs and if sulfide is present at the upper end of a test reach then a depletion of sulfide will occur.

At the gravity sewer sites an effort is made to evaluate the variables which affect the balance between generation on the one hand and oxidation plus evolution on the other.

At siphon sites, evolution of H_2S to the atmosphere is non-existent and oxidation of sulfide ion is limited to the oxidation by dissolved oxygen and other oxidizing agents in the flow at the beginning of the siphon.

At the evolution site it is proposed to gather data which will relate the rate of loss of H_2S to the atmosphere to sulfide content of the sewage, turbulence, pH, temperature and possibly other factors. These same variables will also be related to any corrosion of the sewer pipe that occurs.

DESCRIPTION OF PROCEDURE

At gravity sewer sites measurements are made during each test of eight different variables that are believed to influence sulfide conditions.

During a test measurements are made at three different locations. The "Upper Manhole" (U M) which is the manhole at the upstream end of the test reach, the "Lower Manhole" (L M) which is at the downstream end of the test reach and the "Feed Manhole" (F M) which is a convenient manhole approximately 3 to 5 minutes flow time upstream of the upper manhole.

During a test, measurements are made of various variables at U M and L M at times which are offset by the transit time of the sewage through the test reach. By this technique measurements are made of the same sewage at each end of the test section.

During most tests at gravity sewer sites, two types of runs are made. These are:

Buildup run or buildup-depletion run. This involves determination of whether buildup or depletion occurs between the two ends of the test sewer. Where dissolved sulfide ion is not naturally present at U M at the time of a test, sodium sulfide (Na_2S) solution is added by a constant rate feeder at F M.

Zinc Run. During this run a zinc sulfate solution is added to the sewage flow at F M in sufficient quantity to react with and precipitate all dissolved sulfide that is present in the sewage or is generated in the sewage in the test reach. Because of the very low solubility of zinc sulfide, the effect of this chemical addition is to remove all dissolved sulfide from the solution and effectively stop all oxidation and evolution of sulfide during the run. The increase in zinc sulfide measured as total sulfide that occurs then during a "Zinc Run" is a measure of the sulfide generation occurring at that time.

To further clarify, the test procedure at a gravity sewer site reference is made to Figures 2, 3 and 4 which are data sheets used in the field and Figure 5 which is a data-computation sheet prepared after the run to develop the calculable information needed in later data analysis.

Some notes on these figures are shown below:

Data Sheets. Figure 2 is a typical data sheet and shows the data gathered at the feed manhole. This manhole is about five minutes upstream of the upper end of the test reach. The sketch of the manhole plan on each sheet shows by an X the point at which the reference point to water surface (R P to W S) measurement is made.

Flow measurement in this case was made with a Palmer-Bowlus slab flume inserted in the sewer at this manhole, and the R P to W S measurement records the h over the crest of the flume to the nearest hundredth of a foot. Measurements are made of pH to the nearest tenth, and temperature to the nearest degree Fahrenheit. Samples were taken in this case at ten minute intervals, and the BOD samples were composited into a single bottle for each hour-long run.

Figures 3 and 4 show the data gathered at the upper and lower manholes respectively. Sampling times are adjusted to account for the transit time of the sewage in the sewer to the nearest minute. Fluorescein dye is used to measure both the transit time and the velocity in the sewer. This operation is recorded in these data sheets.

Figure 5 is a composite calculation and data sheet in which the data are compiled in such a way

that individual samples or sets of data are paired with a time offset corresponding to the transit time in the sewer. In this way measurements on the same sewage are made at each end of the test reach and compared with each other. This comparison reflects the changes that have occurred within the test section.

Some notes on this sheet are as follows:

Column	Comment
000	The chemical being fed (if any) is indentified here, and if the quantity is critical and was measured, the concentration is shown here.
00 & 0	The individual sulfide determinations plus set averages are recorded here.
2	The differences, total and dissolved sulfides, are shown here.
3 & 4	Micro amp readings, and corresponding mg/l are recorded here and then averaged within each data set. Generally, averages are carried to one more significant figure than the original data.
6 & 7	Using Fluorescein dye to note transit time, velocity is calculated to the nearest .01 ft/sec.
8, 9 & 10	At the feeder manhole, values of h for the P-B flume are measured. At the other two manholes the depth of flow as measured in utilized to compute the Q from Q = AV which can be compared with the generally reliable Q from the flume.

DATA ANALYSIS

Sulfide Generation. One fundamental type of run that was proposed for the gravity sewer sites was to feed zinc sulfate into the flow in a quantity sufficient to precipitate sulfide as fast as it is generated and stop oxidation and evolution. The expectation was that these runs would provide a measure of total generation of sulfide that was going on in the sewer.

A total of 34 zinc runs have been made to date. The initial criterion for the amount of zinc dosage to use was any amount sufficient to precipitate all of the dissolved sulfide. Using this criterion, dissolved sulfide was checked at the lower manhole but no record was kept of the exact dosing rate.

Analysis of some of the data led to the realization that some of the zinc doses were in fact suppressing aerobic biological activity as measured by dissolved oxygen utilization, and <u>might</u>, therefore, also be suppressing sulfide generation by anaerobes in the slime layer. It is to be expected that the activity of the aerobic bacteria which are present in the slime layer will be affected sooner than the underlying anaerobes in the layer. Nevertheless, if the sulfide generation measured is to give a true picture the zinc dosage must be controlled to minimize any possible toxic effect of zinc on the sulfur utilizing bacteria.

Tables II and III cover all of the "generation" test runs made to date and disclose some useful relationships. Table III includes those zinc runs on which quantitative figures for the dosing rate are available, and attempts to evaluate the relationship between excess zinc dose and interference with dissolved oxygen absorption which is taken as a measure of suppression of aerobic biological activity.

It is apparent from the data that other factors not here recorded are affecting the result. However, biological suppression did not generally occur where zinc dosage was less than 10 ppm. This factor is being watched closely and zinc dosage is being carefully controlled in the runs that are now being made.

Table II shows the data on generation runs prior to October 16 where generally zinc dosing rate was not known.

It was noted in plotting these data that sulfide generation did not exceed 0.1 mg/l on any line that had less than 15 minutes transit time. This means that while earlier data on lines with lesser transit time are usable, it is highly desirable to work on lines where the transit time is 15 minutes or longer.

In the light of this, a revision has been made of criteria for gravity sewer site selection to 15 minutes minimum detention time instead of 500 feet minimum length. New suitable test sites are now being selected.

Sulfide Oxidation Plus Evolution. Information on these variables will be obtained from the buildup runs, more of which are needed before fruitful analysis can be undertaken.

The data gathered so far in buildup and generation runs have been compiled into summary data sheets. There are included in the Appendix to this report.

Oxygen Absorption in Gravity Sewers. It is generally recognized that sulfide buildup in a free-flowing sewer occurs when the rate of oxygen absorption at the surface of the stream is inadequate to keep up with the oxygen demand of the sewage. Attempts to predict whether or not sulfide buildup will occur, based upon sewage strength, temperature, velocity, and relative depth of flow, have been broadly successful, but it is suspected that the formulas developed thus far do not take full account of all of the factors involved. The studies that have been undertaken provide information on the rates of oxygen absorption, oxygen utilization in the stream of sewage and in the slime layer, and the rates of sulfide production by the slimes. The information will provide a better basis for prediction of sulfide buildup, and improved procedures for sulfide control.

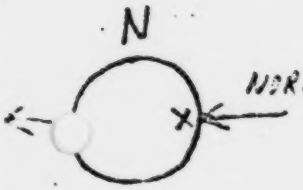
Several papers have appeared in the literature on the rate of absorption of oxygen by streams. It is well known that in the case of sewage the oxygen transfer rates are much slower than with pure water. It does not appear that enough data are available in the literature to allow dependable predictions of the absorption rates in sewers, so experiments have been undertaken to secure data with this end in view.

The coefficient of oxygen absorption can be determined by measurements of the dissolved oxygen concentration at the two ends of a test reach, provided oxygen consumption can be stopped. After some preliminary experiments with sodium pentachlorophenate,

FIGURE 1

LOS ANGELES COUNTY SANITATION DISTRICTS

SULFIDE RESEARCH DATA SHEET



Monitoring Data

Test Site No. 18D

Date 11-27-68 Observer LIVINGSTON Trunk GARFIELD DIVERSION

Test Point Description and Station VIA CONDO W. OF GARFIELD

Type of MH.: (Feed & Weir MH.) Upper end MH, Intermediate MH, Lower end MH.

Reference Point (R.P.) Description _____

Type of Flow Measuring Device: (Flume) Weir, Salt RP to invert _____

D. O. Meter Calib. No. — / mg — at — °F RP to throat or crest 8.29

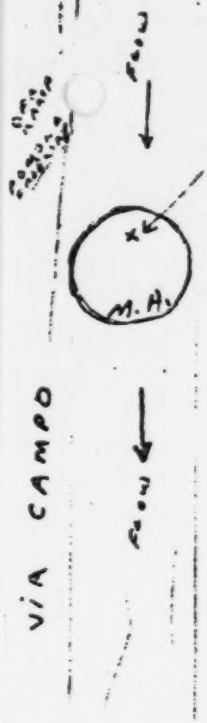
Time	Sulfide Total	Sulfide Diss.	Co-[illegible]ulite	D.O. mg	Temp. °F	pH	R.P. to W.S.	BOD Bottle Number	Notes
10:20									on 7'1 S
10:30				—	77°	8.0	[illegible]	18D-1	
10:40				—	77°	8.1	[illegible]	18D-1	
10:50				—	77°	8.0	8.01	18D-1	
11:00				—	78°	8.1	8.02	18D-1	
11:10				—	77	7.9	8.02	18D-1	
11:20				—	78	8.1	8.03	18D-1	
11:30				—	78	7.8	8.03	18D-1	OFF W/S
			L	U	N	C	H		
12:15									ON W/S
12:30							8.05		
12:40				—	77°	7.9	8.05	18D-2	
12:50				—	78°	7.7	8.04	18D-2	
1:00				—	77°	7.7	8.04	18D-2	
1:10				—	78°	7.6	8.04	18D-2	
1:20				—	77°	7.7	8.05	18D-2	
1:30				—	77°	7.9	8.05	18D-2	
1:40				—	77°	7.8	8.04	18D-2	
1:50				—	77°	7.7	8.05	18D-2	OFF W/S
2:00									STARTED
2:10				—	76°	7.6	8.05	18D-3	150 ml/min
2:20				—	78°	7.9	8.04	18D-3	
2:30				—	77	7.5	8.04	18D-3	Figure 2

FIGURE 3

LOS ANGELES COUNTY SANITATION DISTRICTS

SULFIDE RESEARCH DATA SHEET

Monitoring Data



Test Site No. F-D

Date 11-27-68 Observer Boyington Trunk GARFIELD DIVISION

Test Point Description and Station 1 MI. W. OF GARFIELD ON VIA CAMPO

Type of MH.: Feed & Weir MH, Upper end MH, Intermediate MH, Lower end MH.

Reference Point (R.P.) Description _____

Type of Flow Measuring Device: Flume, Weir, Salt

D. O. Meter Calib. No. P-145 in 18.8 at 77 °F

RP to invert 11.89

RP to throat or crest _____

Time	Sulfide Total	Sulfide Diss.	Composite	D.O. mg/l	Temp. °F	pH	R.P. to W.S.	BOD Bottle Number	Notes
10:15			1ST DYE POUR				11.47		1 QT
10:30	0.6			4.4			11.47		NOAS
10:40	0.6	0.25		4.6	77°		11.47		CHECK SMH TOTAL 1.3
10:50	0.6			4.5	77°		11.47		
11:00	0.7	0.3		5.1	78°		11.49		
11:10	0.7			4.7	78°		11.50		
11:20	0.2	0.0		5.0	77°		11.52		
11:30	0.0			4.7	78°		11.53		
11:40				5.0	77°		11.53		BACKGROUND
12:10			2ND DYE	POUR			11.53		1 QT.
12:15	0.0				77°				BACKGROUND
12:33	1.3			4.7	78°		11.54		
12:40	2.7			4.8	78°		11.54		NOAS
12:50	2.7	2.2		4.5	78°		11.54		
1:00	1.6			4.8	77°		11.53		
1:10	1.6	1.6		4.7	78°		11.53		
1:20	1.65			4.7	77°		11.52		
1:30	1.7	1.0		4.4	77°		11.52		
1:40	1.7			4.3	77°		11.52		
1:50	1.6			4.3	77°		11.52		

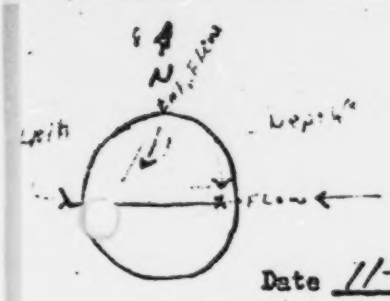
FIGURE 4

1:50

LOS ANGELES COUNTY SANITATION DISTRICTS

SULFIDE RESEARCH DATA SHEET

Monitoring Data



Test Site No. 18-D

Date 11-27-67 Observer Boss Trunk GARFIELD AVE DIV.

Test Point Description and Station S.W.CNR GERHART & POMONA

Type of MH.: Feed & Weir MH, Upper end MH, Intermediate MH, Lower end MH

Reference Point (R.P.) Description ℄ UPSTREAM EDGE

Type of Flow Measuring Device: Flume, Weir, Salt RP to invert 16.42

D. O. Meter Calib. No. 147 in 11.8 at 77 °F RP to throat
1st 2nd

CALIBRATION SAMPLE - 1.7 & 1.3 (ZN Not Added to Samples so they VARIED

Time	Sulfide Total	Sulfide Diss.	Concentration	D.O. mg/l	Temp. °F	pH	R.P. to W.S.	DOD Bottle Number	Notes
SHUT 11:00 10:15			DYE POURED						
10:20	0.1			1.8	77		15.75		BACKGROUND
10:30	0.1			1.8	77		15.75		
36 MIN 10:41.30	FIRST SHOW of DYE								
TRANS TIME 10:52.07	LAST SHOW of DYE								
11:06	0.4			1.7	78		15.80		START #1 NaS Run
11:16	0.4	0.0		1.3	78		15.80		The Supernatant of
11:26	0.5			1.6	78		15.80		the dissolve samples
11:36	0.45	0.1		1.8	78		15.82		Remained milky.
11:46	0.5			2.1	78		15.85		
11:56	0.4	0.0		2.6	78		15.85		
12:06	0.45			2.1	78		15.85		
12:10	12:05?		DYE POURED						#2
12:37.50		FIRST SHOW					15.85	1	
12:41.00		LAST SHOW					15.85		
39 MIN 1:19	0.3			2.0	78		15.86		START #2 NaS Run
TRANS TIME 1.29	1.6	0.7		2.0			15.87		
1:39	0.7			1.6	78		15.87		
1.49	0.8	0.6		1.1	78		15.87		
1.57	0.85			2.0	77		15.85		FIGURE 4

13-D
11-27-68

GARFIELD AVE DIVERSION — L=2901.06

Figure 5
13-D
11-27-68

Composite - Computation Data Sheet

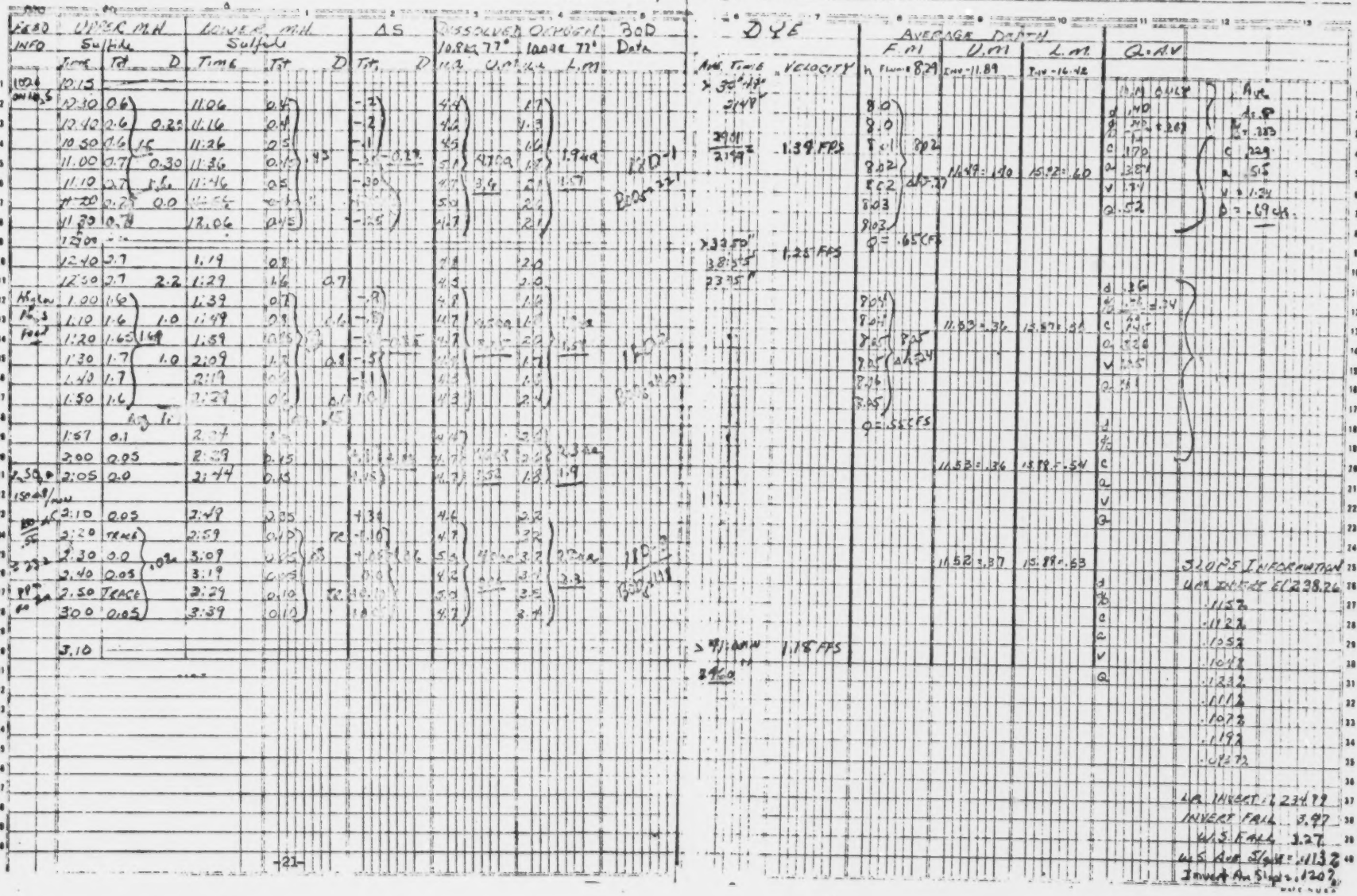


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Fig 5

LOS ANGELES COUNTY SANITATION DISTRICTS
SULFIDE RESEARCH

TABLE II

SULFIDE GENERATION ON RUNS PRIOR TO 10/16/68

Site	Date	Buildup Runs		Zinc Runs			
		Δ T.S.	Δ D.O.	Δ T.S.	Δ D.O.	Increase in ΔD.O.	Transit Time, Min.
18D	7/26	-0.57	-2.8	+0.11	-2.4	+0.4	35
27D	7/30	-0.04	-0.11	+0.15	-0.07	+0.04	16
36H	8/5	-0.16	-0.05	0	+0.12	+0.17	5
27D	8/13	-0.04	-0.01	+0.05	+0.05	+0.06	16
18B	8/20	-0.3	+0.41	-0.01	+0.69	+0.15	5
18C	8/21	-0.05	+0.53	-0.09	+0.99	+0.46	4
27C	8/23	-0.08	+0.13	+0.03	+0.26	+0.13	$7\frac{1}{2}$
27JOJ	8/27	-0.1	+0.31	-0.17	+0.19	-0.12	$17\frac{1}{2}$
21GR	8/30	+0.16	-0.03	+0.24	-0.34	-0.31	$18\frac{1}{2}$
18F	9/5	-0.17	-0.4	0	+0.11	+0.51	7
18J	9/6	-0.22	-0.65	+0.03	-0.30	+0.35	$6\frac{1}{2}$
18H	9/11	+0.06	-0.39	0	-0.04	+0.35	$8\frac{3}{4}$
36K	9/20	+0.05	-0.67	+0.05	-0.32	+0.35	$3\frac{3}{4}$
48A	9/25	-0.06	-0.7	-0.04	-0.9	-0.2	$11\frac{1}{2}$
48B	9/27	+0.16	+0.35	+0.01	+0.76	+0.41	$10\frac{1}{2}$
36C	10/2	-0.60	-0.25	+0.25	-0.5	-0.25	$22\frac{1}{2}$
24B	10/9	-0.26	-1.03	+0.33	-0.76	+0.27	$48\frac{1}{2}$
24B	10/15	-0.30	-1.4	+0.36	-0.2	+1.2	$48\frac{1}{2}$

LOS ANGELES COUNTY SANITATION DISTRICTS
SULFIDE RESEARCH PROJECT

TABLE III

DATA ON BIOLOGICAL SUPPRESSION BY ZINC SULFATE FEED

Site	Date	BUILDUP RUNS Δ T.S.	BUILDUP RUNS Δ D.O.	ZINC RUNS Δ T.S.	ZINC RUNS Δ D.O.	Zinc Dose ppm of Zn	Biological Suppression?	Δ D.O. Increase	T.S. at LM During Run	Approx. Equiv. Zn Dose	Excess Zinc ppm	D.S. at Lower MH
	1968											
60B	10/16	+0.02	-0.1	+0.05	+0.39	8.0	yes	+0.49	0.42	0.8	7.2	0
24B	10/17	+0.42	-0.84	+0.57	+0.39	34.8	yes	+1.23	1.06	2.1	32.7	0
60B	10/24	+0.21	-0.08	+0.01	-0.14	2.1	no	-0.06	0.71	1.4	0.7	0
24B	10/25	+0.16	-0.76	+0.64	-0.86	14.1	no	+0.10	0.84	1.7	12.4	0.13
18D	10/30	-0.62	-1.3	+0.60	-0.4	108	yes	+0.90	0.60	1.2	107	0
18D	10/31	-0.76	-1.98	+0.05	+0.10	106	yes	+2.08	0.05	0.1	106	0
21GR	11/8	-0.06	+0.07	0	+0.12	9.1	no	+0.05	0.04	0.1	9.0	0
27J0J	11/13	+0.06	-0.34	+0.17	-0.14	7.4	no	+0.20	1.15	2.3	5.1	0
27D	11/14	+0.9	-0.32	+0.46	-0.33	19.7	no	-0.01	1.0	2.0	17.7	Trace
10A	11/19	-0.3	-1.5	0	-0.3	24.8	yes	+1.2	0	0	24.8	0
60F	11/22	-0.07	-0.11	+0.02	-0.29	5.5	no	-0.18	0.09	0.2	5.3	0
18D	11/27	+0.10	-1.6	+0.06	-1.8	23.2	no	-0.2	0.08	0.2	23.0	0
	1969											
27J0J	1/30	+0.12	-0.54	+0.45	-0.60	6.8	no	-0.06	0.89	1.8	5.0	0
27J0J	2/4	+0.16	-0.49	+0.5	-0.43	8.5	no	-0.06	1.31	2.6	5.9	0.1
				+0.22	+0.25	25.5	yes	+0.74	1.06	2.1	23.4	0
24B	2/14	+0.40	-1.1	+0.74	-0.50	5.7	yes	+0.6	0.97	1.9	3.8	0.07
				+0.72	0	11.4	yes	+1.1	0.95	1.9	9.5	0

it was concluded that sodium hypochlorite would be better, since it not only effects bacteriostasis, but also oxidizes reducing compounds that react chemically with oxygen. In the preferred method, the sewer is cleaned by the restrained-ball method, then slug treated with sodium hydroxide. The oxygen absorption tests should be made within 48 hours.

At the beginning of the test, a shock dose of hypochlorite is added, and then it is added continuously to give a dosage of 1 to 2 mg/l of Cl_2 during the test. Measurements are made every three minutes for D.O., temperature and sewage depth, with occasional checks for the available chlorine residual.

The effectiveness of the NaOCl treatment is gaged in a bottle experiment, in which a sample from the upstream manhole is retained out of contact with the air for a length of time equal to the transit time for the test reach. In the tests made thus far, no loss of oxygen was shown in the bottle in this retention time.

A few experiments were made with additions of catalysed sodium sulfite to reduce the oxygen concentration to near zero. It was concluded that the uncertainties in attempting to maintain a condition of low dissolved oxygen and zero sulfite at the upper manhole of the test reach made the gain of a greater oxygen deficit a matter of uncertain advantage.

The rate of oxygen uptake by the stream can be expressed by the equation $-\frac{dD}{dt} = KD$ in which D is the oxygen deficit. Integration gives $2.30 \log \frac{D_1}{D_2} = K (t_2 - t_1)$

In the run of January 9, 1969 at Gravity Sewer Site 18D D_1 and D_2 were 3.85 and 3.20 mg/l, respectively and the detention time was .0208 days. The value of K, with time in days, is 8.9.

SULFIDE GENERATION AND CONTROL IN FORCE MAINS

GENERAL

In recent years, the use of compressed air for the control of sulfide generation in force mains has gained increasing attention. The Los Angeles County Sanitation Districts are using compressed air at ten pump stations, and are considering further installations. It is necessary to have more information about the nature of the phenomena involved if efficient and economical designs are to be evolved. Some of the questions to which answers are sought are these:

How fast does air move up the force main, or, what is the retention of air in the main at various air input rates?

At what rate is oxygen absorbed by the sewage at various air input rates?

How much sulfide is produced when air is not used?

At what rate must oxygen be absorbed by the sewage to prevent sulfide buildup?

How does intermittent injection of air compare with continuous injection?

Is it feasible to program the injection rate to conserve power?

Does air injection reduce water hammer?

The studies on the Long Point force main have advanced to the stage where a partial report can be made, and studies have been started at another location. Several mains must be examined if general conclusions are to be reached. The statements made here on the basis of the Long Point force main data obtained thus far must be looked upon as tentative.

DESCRIPTION OF PROCEDURE

Before proceeding to a description of the Long Point force main and data it is in order to describe the test procedure during a sulfide buildup run on a force main and the handling of the data. Reference is made to Figures 6, 7, and 8, which illustrate this procedure as actually carried out at Long Point force main.

The first two of these show typical field data sheets; the third figure is a composite data-calculation sheet.

Some comments on Figures 6 and 7 are as follows:

1. Dissolved Oxygen (D O) measurements are made with semi permeable membrane Dissolved Oxygen meters. These are calibrated by noting the micro amp reading in saturated water at a given temperature. Micro amp readings are then directly proportional to dissolved oxygen in the sample.

2. Air injection rates and injection pressures are different when the sewage pump is on and off. However, in this case off time is usually 20 to 30 minutes compared to an on time of about 55 seconds. Consequently, the change in air injection rate during the sewage pump "on" time has a minor effect on the total amount of air injected during the test.

3. At the beginning of each day's filed work, the men at each end of a test reach determine total sulfides on identical check samples. This serves as a check on the accuracy of the methylene blue test kits.

4. Dye is used on each run to check the sewage transit and detention time.

5. Based on this transit time samples are offset so that paired samples are of the same sewage at the two ends of the force main.

6. Dissolved oxygen and temperature are measured at least once during each pump "on time" at each end of the force main and pH is measured at one end at least once during each pump cycle.

7. At this particular site two samples were taken during each pump "on time," one 20 seconds and another 40 seconds after the pump turns on.

8. On this particular run a separate BOD sample was taken once during each pump "on time."

Comments on the composite data-calculation sheet, Figure 8, are as follows:

Column	Comment
000	Pump "on times" are numbered consecutively from the time the test begins. These "pumping numbers" are the same at both ends of the force main.
00	Pump on and off times are recorded to the nearest second.
0	The pump stayed on each time from 45 to 60 seconds.
1	Off time tends to vary with the time of day. All of the flow into this pumping plant comes from Marineland via a prior pumping with the pump at Marineland. This pump stays on for a much longer time than the Long Point pump. Because of this, there are occasional off periods of as little as three or four minutes instead of the usual longer period.
2	Samples are matched so that paired samples represent the same sewage going into the force main and coming out. This matching is done by noting the cumulative "on time" between two samples. Samples are paired when this "on time" corresponds to the on time required for one turnover of force main contents. In this case the time for a turnover was noted to be 434 seconds.
3 & 4	The detention time is determined by subtracting the inlet time from the sampling time for each sample.
5 & 6	Positive S means that a buildup in Total Sulfide has occurred during the time in the force main. S is occasionally negative.
9 & 10	Similarly the change in Dissolved Oxygen (D.O.) may be positive or negative depending on whether a buildup or depletion occurs.

Description of the Long Point Force Main. The main is 1760 feet long, made of 10-inch AC pipe. Beginning at the pump end, the profile is

Length of Segment feet	Slope %
79	0.26
350	3.515
90	6.278
550	1.180
660	1.194
30	2.20

When not pumping, the pipe is only partly filled for the last 44 feet. The actual holding volume is 7,100 gallons. The wetted wall area is 4,600 square feet.

It requires 7½ minutes of pumping time to displace the water in the main. Thus, the pumping rate is 950 gpm, and the velocity while pumping is 3.9 fps. The actual flow is relatively small, averaging about 45 gpm during the day.

For experimental purposes, the air injection system includes a receiver for the compressed air, a rotameter, and valves to waste part of the air and to put part of it through the rotameter into the pipeline. With the valves set, the rate of air injection changes somewhat when the pump comes on because of a change in the back pressure, but in this situation, with the pump running only about 5% of the time, the effect on the total air input is slight and can be neglected.

DATA ANALYSIS

Sulfide Buildup with and without Air. Tests of sulfide buildup were basically similar to the tests in gravity lines, in that paired samples were compared from the two ends of the force main, but in this case the samples were matched on the basis of 7½ minutes of pumping time. The total elapsed time was generally between 100 and 200 minutes. Two sulfide samples and one BOD sample were taken from the discharge on each pumping.

It was planned that various air injection rates would be tried with the aim of finding what rate would just effect sulfide control. It soon became apparent that under marginal conditions the discharge would sometimes have no sulfide and at other times would have quite high concentrations. The differences are attributable to changes in the sewage.

A measure of the sulfide-producing potential of sewage is desired. It has been shown in previous researches that the biochemical oxygen demand test provides an approximate measure of this potential. The temperature function, expressing the increase of 7% per degree centigrade in the rate of biochemical reactions in general, is combined with the standard 20°C, 5-day BOD to give the "effective BOD" or EBOD:

$$EBOD = BOD \times 1.07^{(t-20)}$$

It is recognized that BOD is not an ideal indicator and it is hoped that a better one eventually will be found.

The problem of determining the proper application of air can be approached by the technique of applying air at a fixed rate and observing the correlation of the rate of sulfide production with the EBOD. Since the concentration of sulfide coming out of the force main is proportional to the detention time, the sulfide production should be expressed as a rate per unit of time.

Table IV summarizes the sulfide buildup tests in the Long Point force main as obtained up to this time. The sewage at the pump station, having already come through one force main, usually carries sulfide, sometimes at concentrations as high as 4 or 5 mg/l. The change of sulfide concentration upon passage through the force main was calculated from matched samples at both ends determined by allowing 7½ minutes of pumping time. Buildup appears as a negative quantity when the initial sulfide concentration is reduced.

In Figure #9, all tests obtained with air injection rates between 1.44 and 1.69 cfm are plotted as sulfide buildup rate vs. effective BOD. The points are quite scattered, but there is a general trend, indicating that when the condition is marginal in respect to sulfide buildup the effective BOD will usually be between 100 and 220 mg/l.

The formula previously published for estimating the upper limit of expected sulfide buildup in a force main is

$$C_s = KtC_{EBOD}\frac{(1+0.01d)}{d}$$

in which C is the concentration of sulfide or EBOD, as indicated, in mg/l, t is detention time in minutes, d is pipe diameter in inches, and K is a constant of the equation. A value of K = 0.0026 is recommended where the detention time is between one and five hours. With this equation, the possible buildup in the force main with no air, under the conditions of the first test in Table IV, would be 16.3 mg/l, compared to 13.3 actual buildup observed.

Oxygen Absorption from Injected Air. On February 5 and 6, 1969, tests were made of the oxygen concentration in the air coming out of the force main. The tests were run with the pump station shut off, since it is possible to do this for several hours. Since there is an air space in the last part of the force main, a plywood disc with a hole in it was placed over the end of the pipe. The air coming out of the hole was drawn into the oxygen analyser.

At the start of the run on February 5, 1969, the air was shut off 90 minutes to allow depletion of oxygen, and then was injected at various rates, with waiting periods between. It was necessary to allow time for the air in the space at the end of the force main to be replaced, so readings were taken until steady values were obtained. In some cases, the oxygen concentration passed through a minimum after starting the compressor. One possible explanation is that there may be places where air hangs up in the pipe when the compressor is off, and that this air, after losing oxygen to the water, is carried out when the compressor is started again.

The calculation of the amount of oxygen absorbed must take into account the fact that the volume of air issuing from the force main is less than the amount put in, because of the dissolving of oxygen and nitrogen.

Let C_1 and C_2 be the oxygen concentrations in and out of the force main, and V_1 and V_2 be the volumes of air in and out. Let x represent the volume of oxygen dissolved, and let b represent the ratio of the volumes

Figure 6

LOS ANGELES COUNTY SANITATION DISTRICTS

SULFIDE RESEARCH PROJECT

Force Main Data Sheet

Force Main LONG POINT Observer BOYINGTON Date 1-3-69

Test Point Descrip.: Pump Sta. wet well, Pump Sta. piping, End of force main

Volume between High and Low levels in wet well:

1:20 P.M.

R.P. to Low level 16.35 Plan Dimensions _____

R.P. to High level 15.30 Vol. Cu. Ft. _____

Pump Down Distance _____ Vol. Gallons _____

D. O. Calibration: Meter No. 145, Saturation /ua 9.7 @ 68 °F

Pressure Readings: Pump on 21 psi Roto - 22% Pump off 15 psi Rotometer-30% CHECK MADE AT 9:03 A.M.

Air Rate: 30 % Capacity at 100% 3.54 c/s. Rotameter Pressure 15 psi

SUCTION PUMP # 2 ON Check sample 4.5

On Time No.	Time: Pump turns on	Time: Pump turns off	Sample Time	Sulfide: Total	Sulfide: Diss.	D.O. /ua	Temp. °F	pH	BOD Bottle No.	Notes
	8:45 A.M.	DYE POURED (2 lbs)								
	8:45	CHECK	SAMPLE	4.5						
①	9:03:50	9:04:45	9:04:17	0.3		5.0	68°	7.7	①	TRAVEL TIME 55 SEC.
			9:04:30	0.3		5.0	68°	7.7		
②	9:09:00	9:04:50	9:09:20	0.4		5.0	68°	7.6		50 SEC.
			9:09:40	0.45		5.0	68°	7.6	②	
③	9:42:15	9:43.11	9:42:35	0.5		4.4	68°	7.9	③	56
			9:42:55	0.45		4.4	68°	7.9		
④	9:51.05	9:52.02	9:51:25	0.3		4.2	68°	8.1	④	57
			9:51:45	0.2		4.4	68°	8.2		
⑤	10:02.45	10:03.41	10:03:05	0.45		7.2	68°	8.4	⑤	56
			10:03:25	0.55		7.1	68°	8.4		

Figure 6

Figure 7

LOS ANGELES COUNTY SANITATION DISTRICTS

SULFIDE RESEARCH PROJECT

Force Main Data Sheet

Force Main Long Beach Observer Bass. Date 1-3-69

Test Point Descrip.: Pump Sta. wet well, Pump Sta. piping, End of force main

Volume between High and Low levels in wet well:

R.P. to Low level _____ Plan Dimensions _____

R.P. to High level _____ Vol. Cu. Ft. _____

Pump Down Distance _____ Vol. Gallons _____

D. O. Calibration: Meter No. 147, Saturation µa 8.8 @ 69.5 °F

Pressure Readings: Pump on _____ Pump off _____

Air Rate: 31 % Capacity at 100% _____ Rotameter Pressure 15 lbs.

Check Sample = 4.5

on time #	Time Pump turns on	Time Pump turns off	Sample Time	Sulfide Total	Sulfide Diss.	D.O. µa	Temp. °F	pH	BOD Bottle No.	Notes
(5) 60sec	10:28:45	10:29:45		0.2						
				0.2		2.0	70°			
(6) 55sec	11:10:40	11:11:30		0.0						
				0.0		2.6	70°			
(7) 55sec	11:16:00	11:16:55		0.0						
				0.0		2.8	70°			
(8) 55sec	11:50:30	11:51:25		0.1						
				0.0		3.2	70°			
* (9) 55sec	11:55:20	11:56:25		0.0						DYE
				0.1		3.3	70°			ARRIVED
(10) 55sec	12:21:00	12:21:55		0.0						
				0.4		2.8	70°			
(11) 50sec	12:26:05	12:26:55		1.2						
				1.5		3.0	70°			
(12) 56sec	12:57:40			8.0						
				5.0		0.4	69°			
(13) 45sec	1:02:20	1:03:05		5.4						
				6.0		0.5	68°			

Figure 7

Figure 8

1-2-69

Long Point

Air 803

Long Point Fish Trap

Composite Data Calculation Sheet

Set DO 1.2 ppm

65° = 9.24 ppm

	Pump Times	JN Time	Off Time																				

TABLE IV

AERATION EXPERIMENTS, LONG POINT FORCE MAIN

Air Injection, cfm	BOD	Temp. °C	C_{EBOD}	ΔC_s	Detention Time, minutes	Rate of Build-up, mg/l per hour
0	226	24	296	13.2	192	6.9
1.44	359	21	384	10.7	201	3.2
1.44	315	21	337	14.7	237	3.7
1.44	250	21	258	18.4	202	5.5
1.49	103	22	118	11.5	210	3.3
1.49	210	20	210	-0.25	192	-0.1
1.49	503	20	503	6.25	182	2.1
1.49	460	20	460	5.20	154	2.0
1.49	190	20	190	7.55	122	3.7
1.59	222	21	237	1.05	177	0.4
1.59	204	21	218	1.0	179	0.3
1.59	103	21	110	0.4	166	0.1
1.59	132	21	141	0.05	145	0.0
1.59	155	21	166	2.9	146	1.2
1.59	126	21	135	0.3	130	0.1
1.59	127	21	136	0.0	130	0.0
1.59	204	19	191	3.8	151	1.5
1.59	283	19	265	-0.45	103	-0.3
1.59	250	19	234	0.45	100	0.3
1.69	95	21	102	1.2	193	0.4
1.69	261	21	302	13.6	173	4.7
1.69	283	21	326	15.5	201	4.6
1.69	324	21	374	11.2	109	6.2
1.69	260	21	300	6.6	131	3.0
1.69	237	21	273	7.2	136	3.2
1.69	264	21	304	7.6	145	3.1
2.58	210	23	257	-2.1	200	-0.6

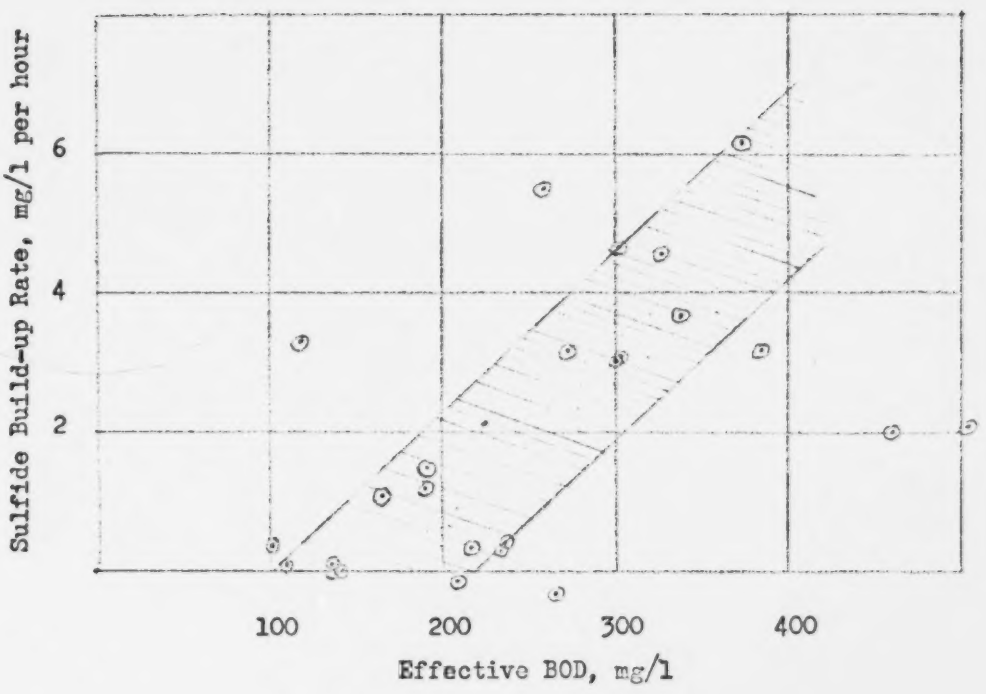


Figure 9. LONG POINT FORCE MAIN AERATION STUDY

Sulfide Build-up Rates With Air
Injection Rate 1.44 to 1.69 cfm

of nitrogen and oxygen dissolved. Then

$$V_1 - V_2 = (1+b)\ x$$

$$C_1V_1 - C_2V_2 = x$$

Combining these equations gives

$$x = \frac{C_1 - C_2}{1-(1+b)\ C_2}\ V_1$$

Only a rough estimate can be made of the amount of nitrogen dissolving in the water. At ordinary temperatures, the solubility, on a volume basis, of atmospheric nitrogen is 2.1 times the solubility of atmospheric oxygen (1.84 times on a weight basis). The diffusion coefficient of nitrogen in water is probably about 8% greater than for oxygen. The ratio of the volumetric rates of solution from air into completely deaerated water would presumably be about 2.1 x 1.08 = 2.3. For other than deaerated water, the rates would be influenced also by the driving force; that is, the difference between the concentration of the gas already in solution and the saturation concentration.

In the Long Point force main, the average pressure over the entire length of the main, with no flow, is 13.4 feet of water or 0.4 atmosphere. If the sewage initially carries nitrogen at a concentration in equilibrium with the atmosphere, and zero dissolved oxygen, the driving forces for dissolving nitrogen and oxygen are respectively 0.4 and 1.4 atmospheres. The relative rates of solution, on a volume basis, would be

$$2.3 \times \frac{0.4}{1.4} = 0.7 = b$$

The oxygen concentration was kept low by allowing time for substantial biological depletion between runs. The oxygen taken up during the first run, with air injection at a rate of 0.99 cfm, amounted to only 0.4 mg/l, equivalent to an atmospheric pressure of 0.05 atmosphere.

Before the first run, air was injected at a rate of 8 cfm for 30 minutes. It is estimated that this reduced the nitrogen deficit, relative to the average pressure, from 0.4 atmosphere to 0.13 atmosphere, and that at the end of the run the sewage was near equilibrium with nitrogen. It is concluded that the effect of dissolving nitrogen is so small that it can be neglected, letting b = 0.

Another minor factor is the increase of water vapor in the air. The air will come out of the main in approximate equilibrium with water at atmospheric pressure. If the water vapor content of the air entering the compressor was half as great, the evaporation of water would add about 1% to the volume of the air. A correction could be made by measuring or estimating the water content of the air supply. This has not been attempted for the Long Point force main.

The treatment here given uses only the average pressure in the force main. A more rigorous procedure would take into account the varying pressure along the length of the main.

Data and results of the calculations are shown in Table V.

At the lower rates of air injection, the absorption of oxygen appears to be nearly proportional to the rate, about 1.75 g per cu. ft. of air, or 22% of the amount of oxygen in the air. The injection pressure is 15.0 psi. The theoretical power requirement for adiabatic compression of air to 15.0 psi is 0.050 hp-hr per cfm. From these figures the power efficiency is 4.6 lbs oxygen per theoretical horsepower-hour (1.56 kg per theoretical kw-hr.). In terms of actual electrical input to the motor, the solution rate may be about 2.0 lbs per kw-hr consumed. Commercial aerators claim higher power efficiencies, but their ratings are against pure water. The rate of solution of oxygen into sewage is expected to be only 40% to 50% of the rate for pure water. In comparison with other methods of aerating sewage, the method of injecting air into this force main shows good efficiency, but is not exceptional. This is at low rates of injection. At higher rates, the efficiency would be considered rather poor.

At the average rate of air injection in the tests represented by Figure 9, the rate of oxygen absorption is 2.6 grams per minute or 156 grams per hour, or 5.8 mg/l per hour. It appears that this amount of oxygen would prevent sulfide buildup when the effective BOD is somewhere between 100 and 220. The sewage must be able to consume oxygen at least that fast, or at a rate of roughly 3% to 4% of the 5-day BOD per hour. This relatively high rate of consumption is a further demonstration of the "trickling filter effect" in the force main.

TABLE V

OXYGEN ABSORPTION DATA

Time		Rate	Oxygen	Reduction	Oxygen Absorbed		
Air On	Air Off	cfm of Free Air	Concentration %	of Oxygen Concentration	% of Air Added	cfm	Grams per Minute
Feb. 5, 1969							
11:50	12:05	4.96	18.8	2.2	2.71	0.134	5.0
12:30	12:45	3.97	18.3	2.7	3.31	0.131	4.9
13:05	13:25	2.98	18.05	2.95	3.60	0.107	4.0
13:40	14:00	1.99	17.55	3.45	4.18	0.083	3.1
14:00	14:15	0.99	17.4	3.6	4.36	0.043	1.6
14:30	14:50	2.98	17.3	3.7	4.47	0.133	5.0
Feb. 6, 1969							
10:50	11:30	2.83	18.35	2.45	3.00	0.085	3.2
12:20	13:10	0.71	16.85	3.95	4.75	0.0337	1.25
13:55	14:20	4.25	18.35	2.45	3.00	0.1275	4.8
14:40	14:45	4.96	18.6	2.2	2.70	0.134	5.0
14:57	15:00	5.66	18.9	1.90	2.34	0.132	5.0

Figure 10 is a graphical representation of the data.

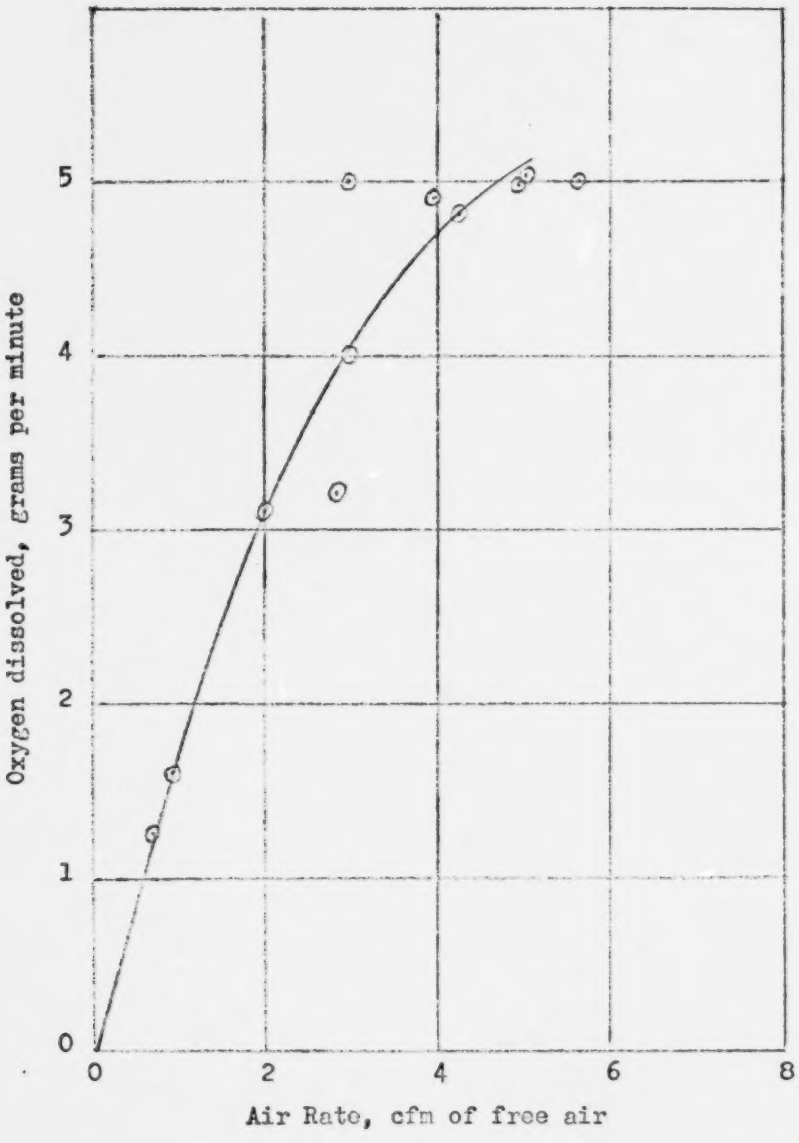


Figure 10 LONG POINT FORCE MAIN
OXYGEN SOLUTION STUDY
February 5 and 6, 1969

The possible rate of sulfide production estimated for the marginal EBOD range would be between 1.7 and 3.8 mg/l per hour. When one part of sulfur is reduced from sulfate to sulfide, 2.00 parts of oxygen are made available. Thus, between 3.4 and 7.6 mg/l of oxygen per hour might be made available. It appears in this case that the amount of oxygen required to prevent sulfide buildup may be similar to the amount made available by the reduction of sulfate when the oxygen is not supplied.

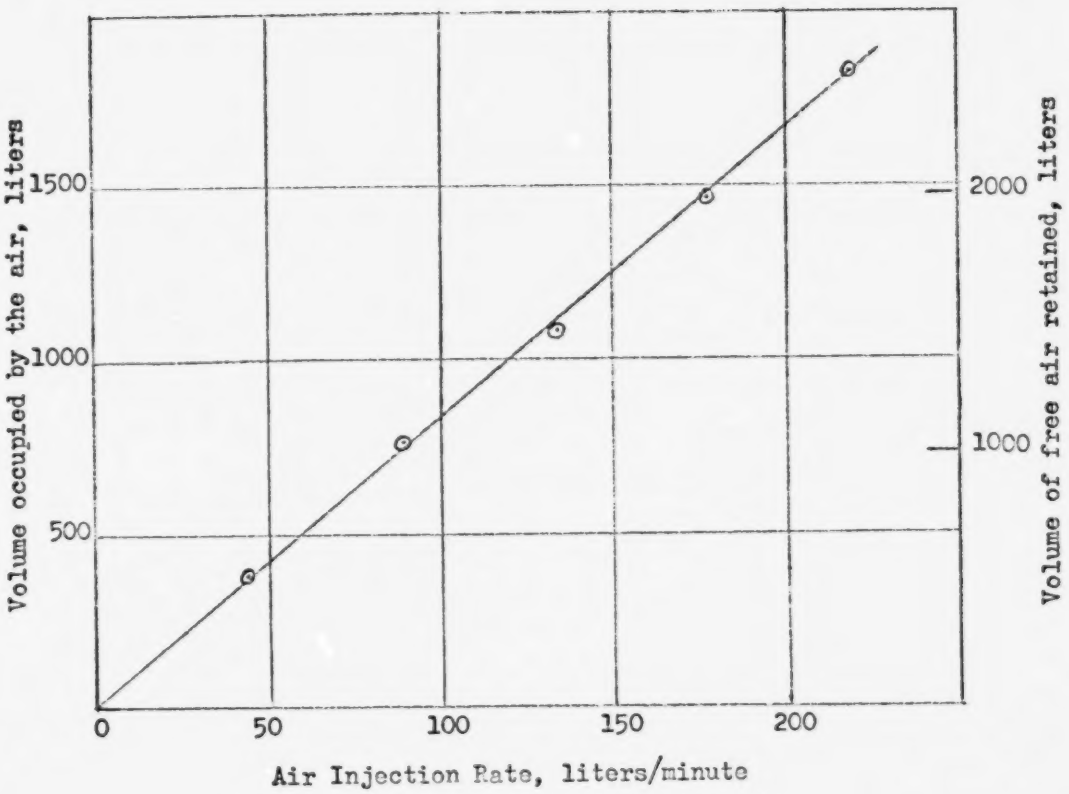
Air Retention in the Force Main. The volume of air held by the force main when air is being injected but the pump is not running can be determined by stopping the air, letting all of the air escape from the discharge end, then determining the amount of water required to refill the pipe. Determinations were made at five air rates. The water was measured by use of a water meter. Results are shown in Figure 11. The linearity of the data shows that the rate of movement of air along the pipe is independent of the amount of air. At the highest rate of injection, 30 liters per minute, the volume of air in the pipe was 1840 liters (485 gallons). It is estimated that the pressure in the force main reduced the volume to about 0.74 of what it would have been at atmospheric pressure. Thus, the pipe held 2490 liters of free air at the prevailing temperature, 21°C. The rate of injection was 225 liters/min. The calculated detention time is 8.2 minutes.

It was reported that air reaches the end of the force main about eight minutes after starting the compressor, but this has not been accurately timed. Perhaps some of the first air bubbles run ahead of the main mass, reaching the end in less than the average time.

LABORATORY WORK

FILLED PIPE TESTS

As the Research Plan was developed in detail it seemed desirable to plan that some tests be carried out in a laboratory scale apparatus that would simulate conditions in a force main but with facilities for varying and controlling significant variables such as the nature and amount of nutrient, velocity in the pipe, the nature of sulfur source compounds and possibly temperature. A design was therefore developed early in the



AIR RETENTION IN LONG POINT FORCE MAIN

FIGURE 11

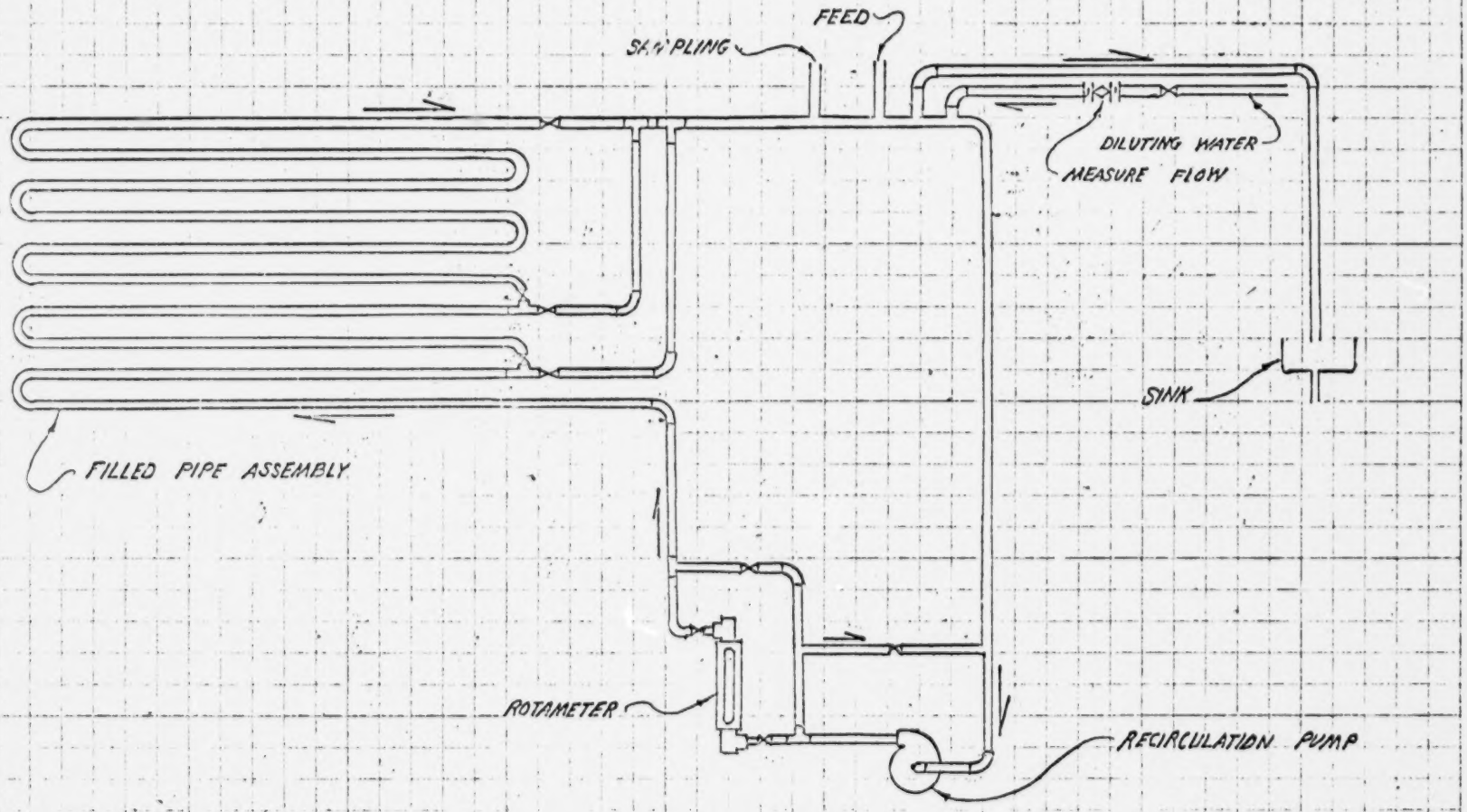
project year for such an apparatus and it was constructed by May 1968. This apparatus is described in three figures. Figure 12 shows a flow diagram, and Figures 13 and 14 show a plan and section of the facility.

This apparatus was experimented with over about a three-month period without conclusive results. Two problems were encountered. First, we discovered that the filled pipe apparatus appears to generate sulfide at a much slower rate than force mains do in the field. Secondly, the addition of supplemental nutrients seemed to have very little effect. After these discoveries the filled pipe apparatus was set aside temporarily and an investigation of nutrient effects through filled bottle tests was undertaken to try to shed light on some of the anomalies encountered. To illustrate the effect that was observed we have tabulated below the results for several typical runs.

SULFIDE GENERATION IN LABORATORY FILLED PIPE APPARATUS

Variable	6/21	6/24	6/26	6/27	7/15
Feed Material	Sewage	Sewage	Sewage	Sewage + 450 ppm Dextrose	Dextrose only
Feed Rate ml/min.	920	430	420	400	1080
No. of Tubes	4	4	4	4	4
Internal Area $ft.^2$	4.69	4.69	4.69	4.69	4.69
Volume of System, gal	14.3	14.3	14.3	14.3	14.3
Detention time, min.	59	126	129	135	50
Recirculates Rate(fps)	1.0	1.0	1.0	1.0	2.0
BOD(est.if bracketed)	(245)	(245)	(245)	(245)	(245)
Temperature °C	25°	25°	25°	25°	28°
EBOD	(344)	344	344	344	421
Stabilized T.S.	0.35	0.65	0.6	0.85	0.7
K x 10^4	.338	.300	.288	.360	.650

FILLED PIPE TEST APPARATUS



FLOW DIAGRAM
NO SCALE

L.A.C.S.D. SULFIDE RESEARCH PROJECT

Figure 12

Figure 12

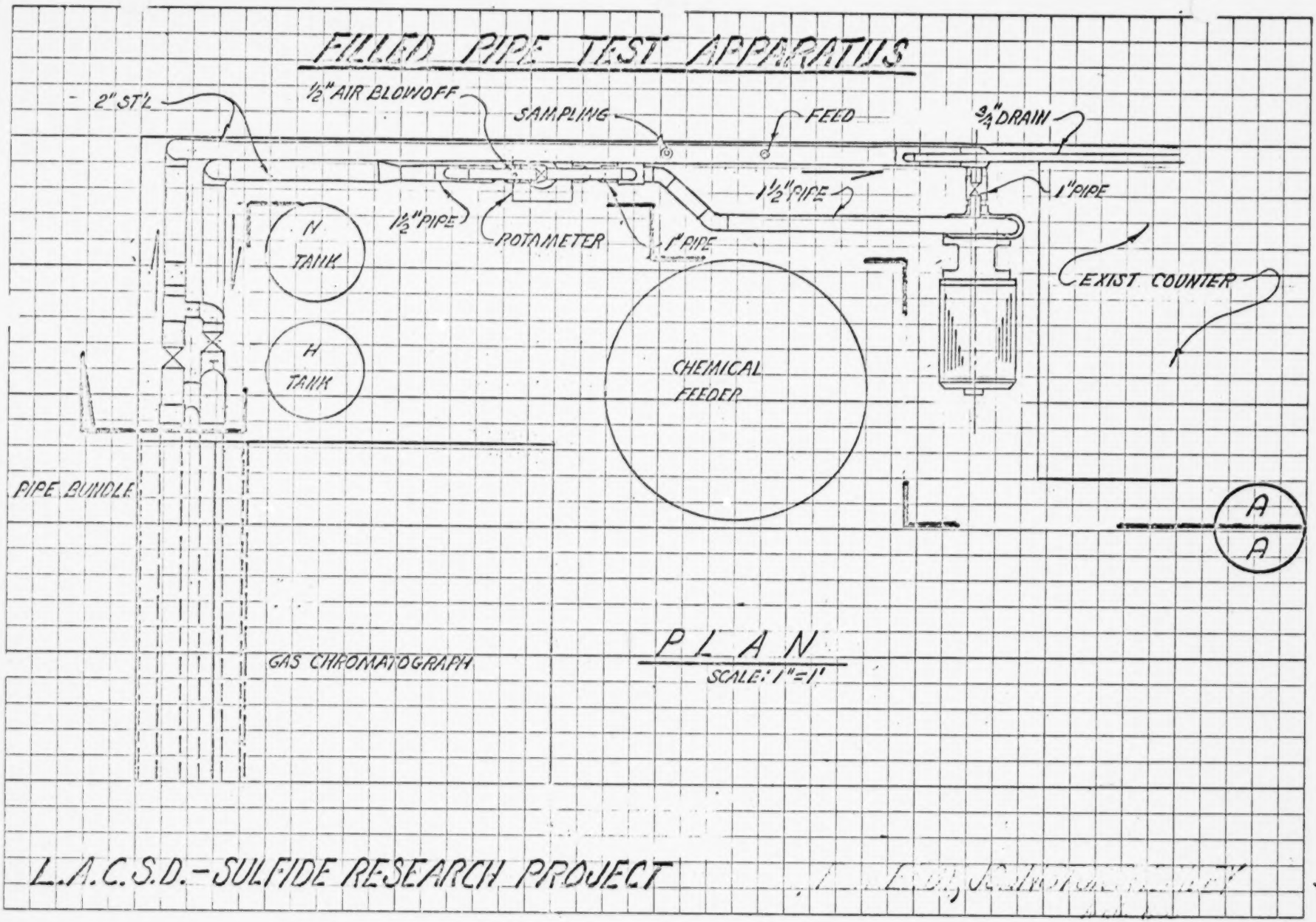


Figure 13

Figure 13

NO. 340-S DIETZGEN GRAPH PAPER
5 X 5 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.

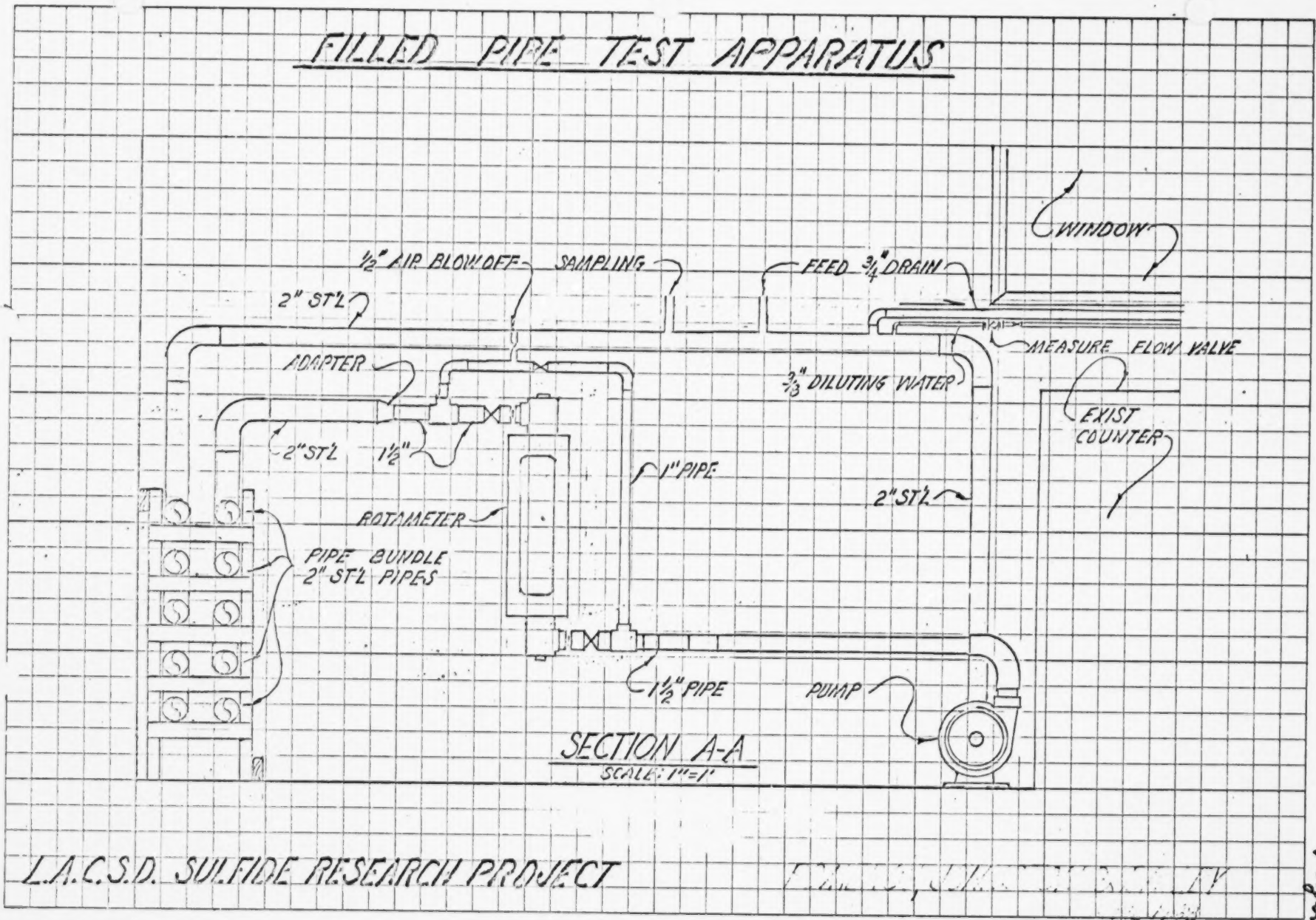


Figure 14

Figure 14

NO. 340-S DIETZGEN DRAPH PAPER
5 X 5 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.

The coefficient K is proportional to the sulfide production in lbs/day/sq ft/mg/l of EBOD. For a description and definition of K, reference is made to "Generation and Control of Sulfide in Filled Pipes" Sewage and Industrial Wastes 31 No. 9, 1959, page 1083, by Richard D. Pomeroy.

In that paper, data are cited for 44 force mains. In these, values of K varied from 2.8×10^{-4} to 64.2×10^{-4}. It will be seen from this that the values of about 0.3×10^{-4} obtained in the laboratory filled-pipe apparatus indicate a very low rate of sulfide production. Further experiments are now being planned to try to trace down this discrepancy.

BOTTLE TESTS OF NUTRIENTS

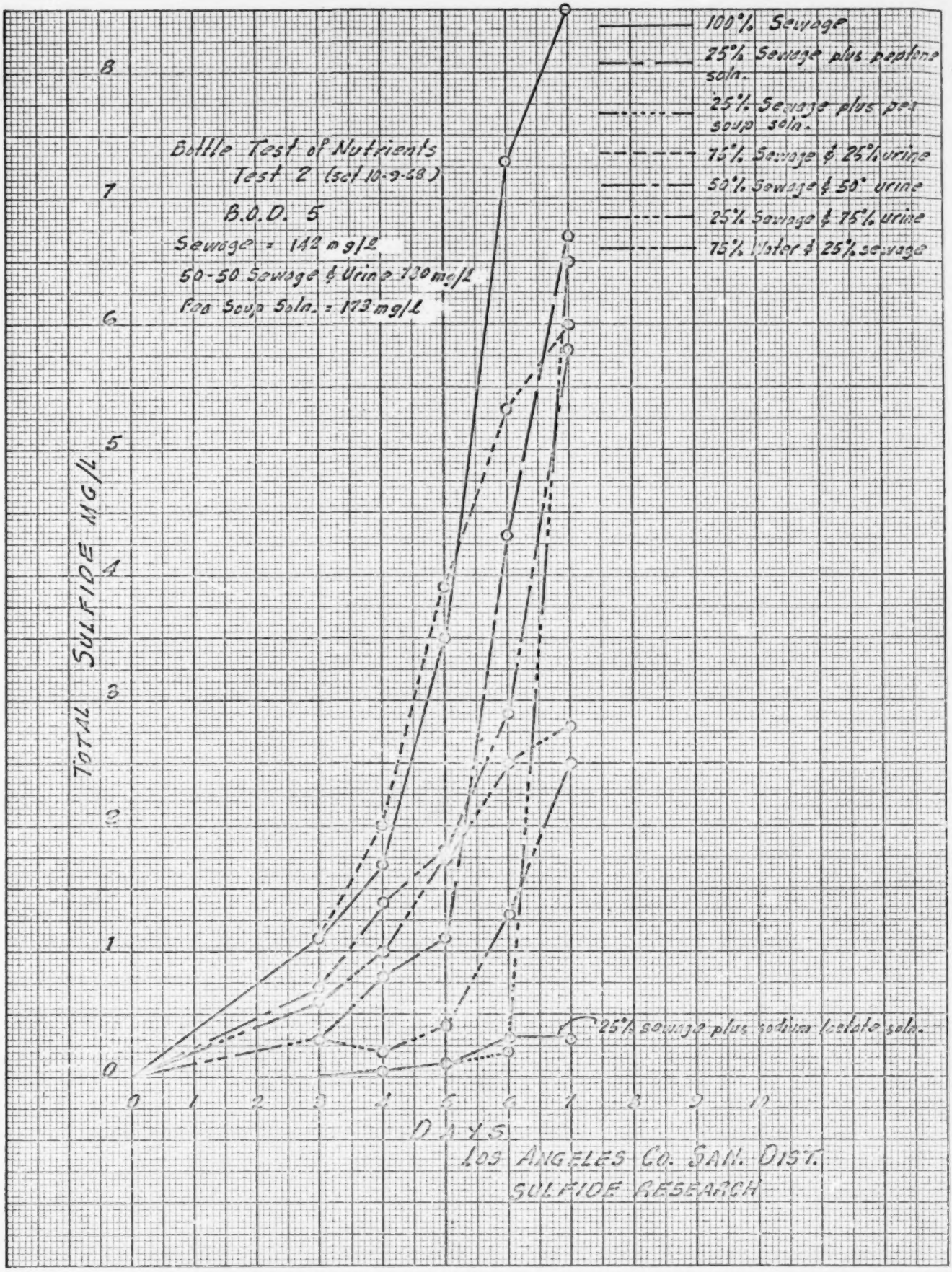
Bottle tests offer a simple method to get preliminary information on the influence of various factors affecting the bacterial reduction of sulfur compounds to sulfide. The conditions in a filled bottle are, of course not the same as those in a flowing sewer. Results therefore must be interpreted with care and any insights obtained should be verified in sewers, or by other experiments which utilize conditions more closely parallel to those in a sewer.

A principal difference between bottle and sewer tests is the lag that occurs in a bottle due to the absence of a suitable, developed, bacterial culture. The sewage samples are always seeded so bacterial growth does eventually occur. However, the lag must be expected and bottle tests must extend for several days instead of hours as is the case with experiments in sewers. The results of some nutrient bottle tests are shown in Figures 15, 16, 17 and 18. The discussion below covers some general description of how the tests were performed and certain pertinent observations and conclusions drawn from them.

Generally, the plan was to completely fill a large number of small bottles with the test solutions and to store them in an incubator at 20°C with a water seal. Two bottles are then removed each day and tested for total sulfide. The values shown are averages of the two results at each test time. It is in the nature of sewage samples to be quite variable so averages of two or more bottles are much more reliable than single results.

Test 2 Various Nutrients (Figure 15). Within this test two different series of mixtures were compared with sewage. First three mixtures of sewage and urine were made. These were 25% sewage + 75% urine, 50% sewage plus 50% urine, and 75% sewage plus 25% urine. The two controls that are significant for this series are 100% sewage and 25% sewage plus 75% water.

FIGURE 15



K&E 10 X 10 TO ½ INCH 46 1473
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 15

An apparent conclusion from this series is that the addition of urine results in some slight increase in sulfide generation but this increase is quite small in relation to the increase in BOD_5 which occurs at the same time.

The second series within this same set consisted of mixtures of 25% sewage plus 75% of various stock solutions of various other nutrients.

The stock solutions were:

Pea Soup (Campbells concentrated	2000 mg/l
Sodium Lactate	500 mg/l
Peptone	500 mg/l

The test mixtures consisted of 25% sewage plus 75% of nutrient stock solutions and their results should be compared with the 25% sewage plus 75% water control mixture.

Some conclusions from this series are:

1. Sodium Lactate appears to diminish sulfide generation.

2. Peptone and Pea Soup both stimulate sulfide generation but less than sewage of the same BOD.

Test 2A Various Nutrients Figure 16. In this series mixtures were made up of full strength sewage plus various solid nutrients. The mixtures were as follows:

Sewage only

Sewage plus 500 mg/l Peptone

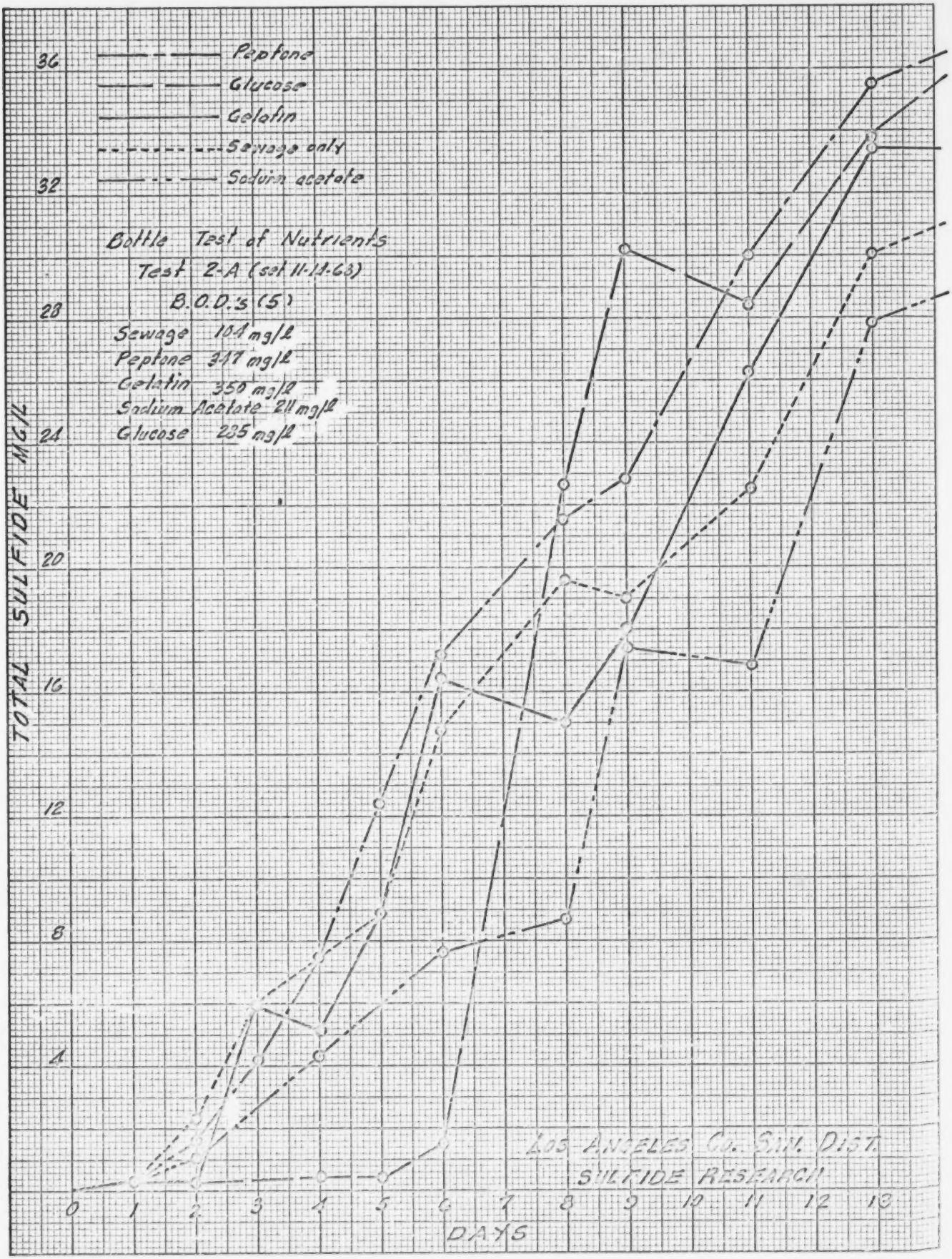
Sewage plus 500 mg/l Gelatin

Sewage plus 500 mg/l Sodium Acetate

Sewage plus 500 mg/l Glucose

Sewage plus 500 mg/l Butyric Acid

FIGURE 16



KE 10 X 10 TO ½ INCH 46 1473
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 16

Conclusions drawn from the results of this series are:

1. The presence of Glucose (Dextrose) leads to fermentation (gas bubbles were observed in the filled bottles). Sulfide generation is prevented until the sugar is fermented to CO_2 and alcohol; thereafter rapid sulfide generation occurs.

2. In this series sodium acetate appears to inhibit sulfide generation during this period of up to 13 days.

3. No sulfide generation occurred in the presence of Butyric acid but this is probably due to the low pH. Later tests in which pH was not a factor gave different results.

4. This series illustrates rather strikingly the observations that nutrient additions to sewage often show large increases in BOD but only small increases in sulfide production.

Some pertinent results are:

Test No.	Sample	BOD mg/l	Increase in BOD %	Total Sulfide mg/l	Period days	Increase in Sulfide %
2A	Sewage only	104	--	30.0	13	--
	Sewage + 500 mg/l Peptone	347	234	35.5	13	+ 18.3
	Sewage + 500 mg/l Gelatine	350	236	33.5	13	+ 10.7
	Sewage + 500 mg/l Sodium Acetate	211	103	27.8	13	- 7.9
2	25% Sewage + 75% water	36	--	2.5	7	--
	25% Sewage + 75% urine	461	1180	2.8	7	+ 12
	25% Sewage + Pea soup solution	165	348	6.5	7	+160

Test 4 Various Nutrients Figure 17. Procedure in this set was identical to that in Test 2A. Full strength sewage was supplemented by 500 mg/l of each nitrient. Some conclusions are:

1. Addition of cellulose, sodium butyrate and isopropanol all resulted in marked stimulation of sulfide generation.

2. Sodium acetate and methanol additions stimulated sulfide generation but only after 15 to 20 days lag period. This suggests that the sewage may have a larger developed bacterial population that can utilize cellulose sodium butyrate and isopropanol, than can utilize sodium acetate and methanol.

Test 5 Sewage of Various Strengths Figure 18. In this series the sewage was diluted or concentrated by vacuum evaporation so that three strengths of sewage were available - ½ strength, full strength, and double.

In the evaporation step a vacuum was used to permit concentration at a low enough temperature to prevent sterilization. After the sewage was concentrated to slightly less than half of its original volume, 100 ml of original full strength sewage was added to 500 ml of concentrate in order to be sure of the presence of adequate seed.

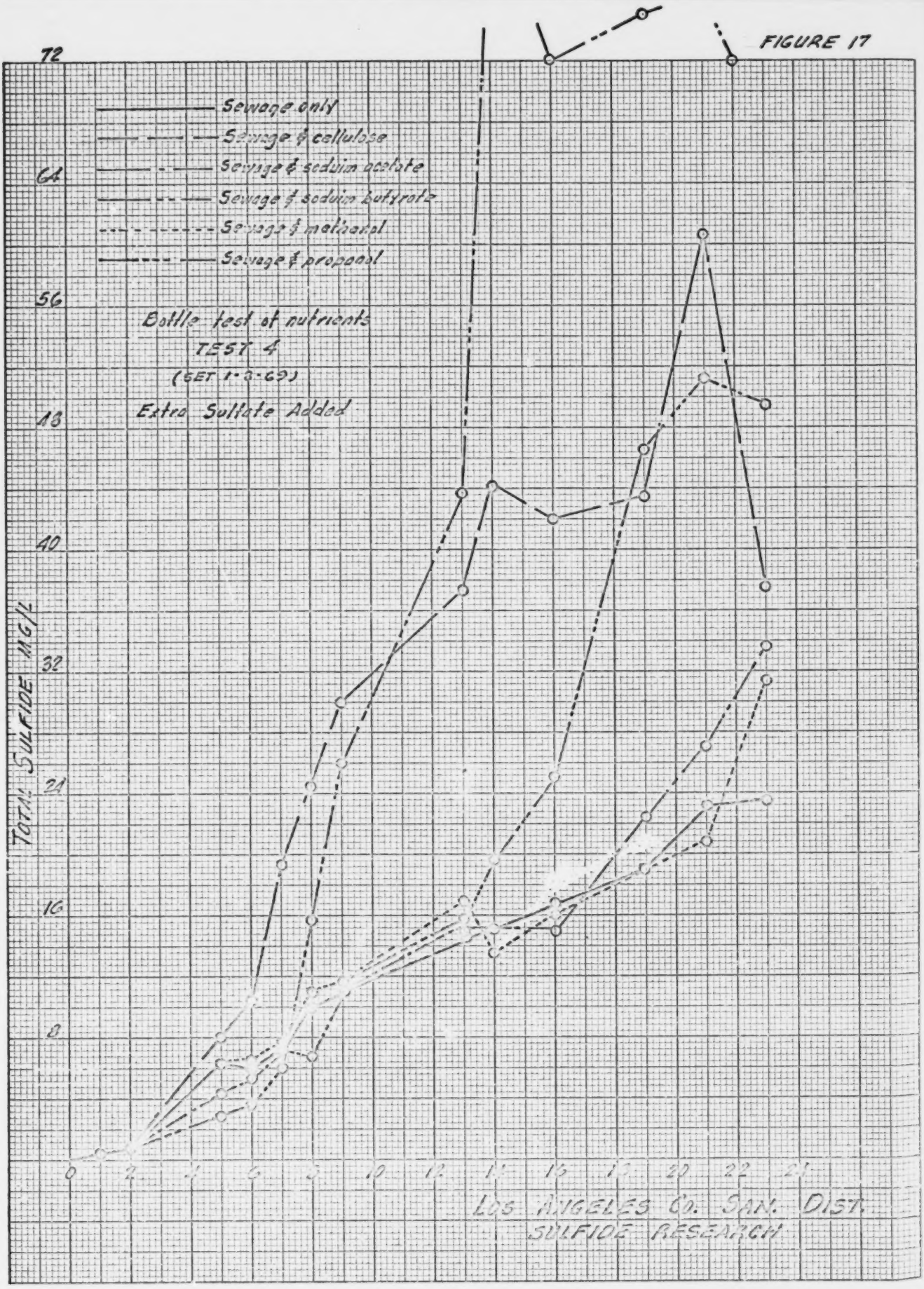
Evaporation also removes CO_2 and results in a marked increase in pH. pH was therefore readjusted back to 7.0 after the concentration step.

Conclusions based on this series are:

1. Half strength sewage produced sulfide almost as rapidly as full strength. This suggests strongly that some other factor than BOD is limiting on sulfide generation in bottles.

2. Double strength sewage produced sulfide at almost the same rate as unconcentrated full strength sewage. No explanation for this is immediately apparent. Further tests on this are now under way.

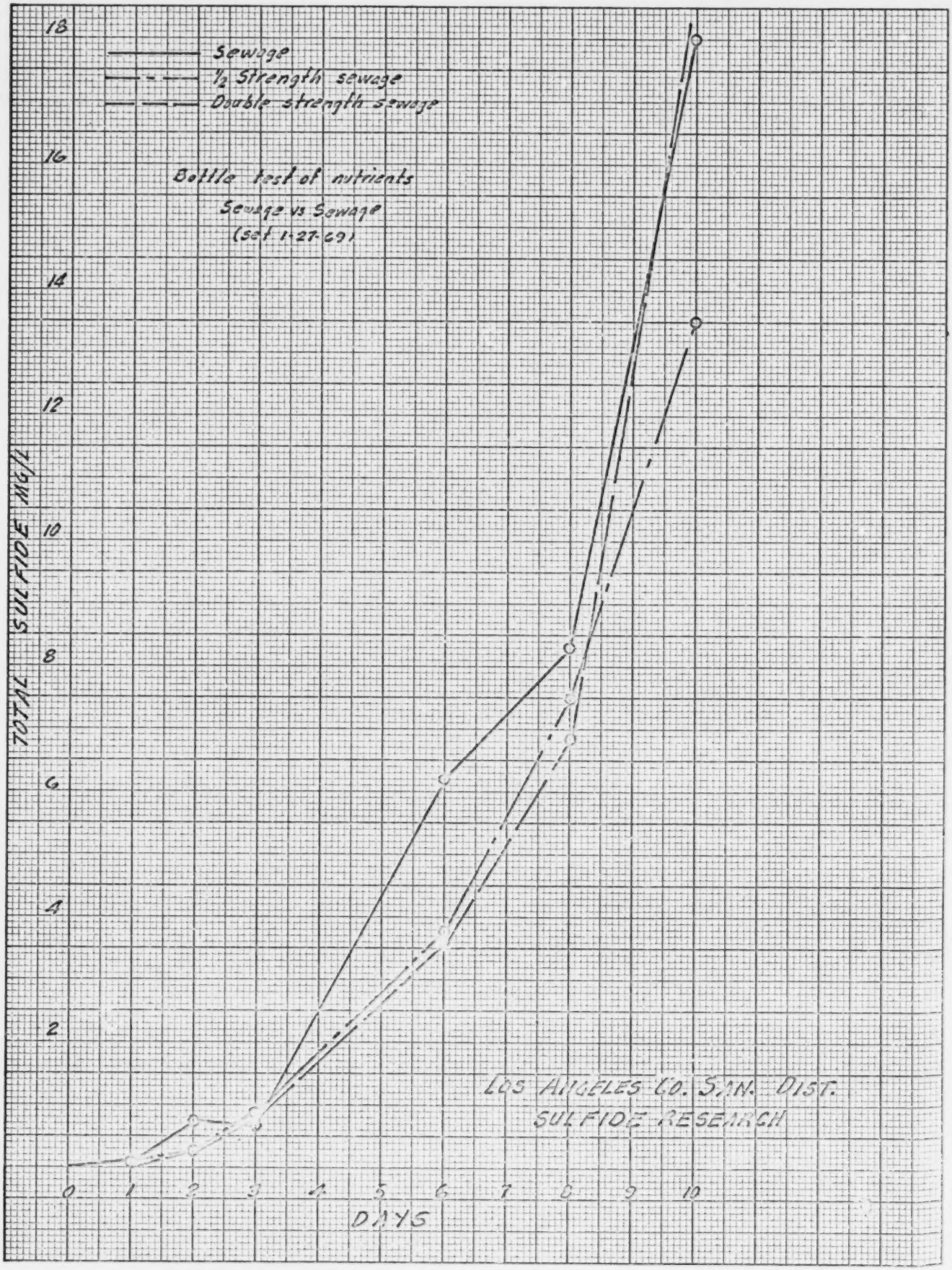
FIGURE 17



KE 10 X 10 TO ½ INCH 46 1473
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 17

FIGURE 18



KE 10 X 10 TO ½ INCH 46 1473
7½ X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 18

REDUCIBLE SULFUR TESTS

There has been a need to assess the effect of the sulfur source compounds on sulfide buildup or generation capacity in a sewer. As data has been gathered during this first project year, there has been a growing conviction that the presence or absence of readily available sulfur source compounds may have a marked influence on sulfide generation in a sewer.

For this reason, a laboratory investigation was undertaken to develop a test that was suitable for measurement of sulfur compounds that are intermediate in degree of oxidation between sulfide and sulfate. There are several such intermediate compounds and all of them are more available for reduction to sulfide than is sulfate ion. It seems advisable therefore to develop such a test which will measure the presence of a wide range of such compounds rather than one particular one.

The test that has been developed for this involves a two stage chemical reduction and will generally need to be carried out in the laboratory on samples gathered in the field, and suitably preserved in the field before transporting to the lab.

It is to be expected, in theory, that sewage that has a long history in sewers will have a higher content of intermediate sulfur compounds than will a sewage of more recent origin. This is due to the repeated oxidation and reduction that sulfur compounds undergo due to varying conditions in the sewers through which the sewage passes.

With this specially developed test it is planned to survey intermediate sulfur compounds in the LACSD system and correlate their presence with the sulfide generation and buildup data that are also being gathered.

IONIZATION CONSTANT OF H_2S

Work was done in March and April 1968 on determining the ionization constant of H_2S. The value of this constant will enter into calculations of the relationship of sulfide evolution rate to dissolved sulfide content, pH and other factors. The values for this constant previously published are known to be inaccurate and better values are badly needed. This portion of the work is nearly completed.

FUTURE WORK

GRAVITY SEWER STUDIES

As has been mentioned in previous sections, data gathering is expected to continue at various gravity sewer sites and siphon sites. Repeat runs will be made on those gravity sewer sites where the transit time exceeds about 15 minutes as experience has shown that with shorter transit time the changes that occur are very difficult to measure accurately. Repeating runs at the same site at a different time of year results in a new set of temperature conditions. Since flow and sewage strength also vary markedly from time to time, these repeat tests will be very useful.

In addition to the repeat tests, it is planned to select at least 10 more new sites with transit time in excess of 1000 secs. (16.7 min.).

As now planned the runs at each site will include buildup runs, zinc runs, and at some sites oxygen absorption tests.

The work at siphon sites will also be repeated during the summer to give data at new temperature conditions.

FORCE MAIN STUDIES

A third "air control assembly" is currently under construction. This will make it possible to gather information at three force main sites at the same time. It is expected here also to repeat some tests at each of the force main sites tested so far. The different temperature and flow condition will result in significant new data from these repeat runs.

It is also planned to complete work on the remaining seven force main sites not yet tested. It is expected that this phase of the work will be essentially completed in the next six to nine months.

LABORATORY WORK

The laboratory research described earlier will be continued in an effort to resolve some of the anomalies and gain some new insight into the best measures of sewage strength and of sulfur source compounds.

SULFIDE EVOLUTION AND CORROSION

There is some uncertainty about how much hydrogen sulfide can be tolerated in the sewage flow and in the sewer atmosphere without danger of significant corrosion. There is evidence that indicates that those allowable quantities may be different under different conditions particularly of turbulence but also of temperature and pH.

It is proposed to run a series of tests at one particular site, described as an evolution-corrosion site which will help define the interrelationships of these factors.

It is planned to install a controlled and measurable turbulence at a particular point in the sewer and then to monitor the sulfide content of the sewage and the sewer atmosphere above and at various points below this point of turbulence. In addition it is planned to measure the corrosion of the pipe wall at various points relative to this "Turbulence Point."

This measurement of corrosion will be a relatively sensitive chemical measurement of corrosion products as they accumulate on the sewer pipe wall. By this method the corrosion rate can be established with great accuracy long before the physical effects of corrosion can be observed.

Selection of an "Evolution Site" as described in the Research Plan was spread out over a considerable period of time. Preliminary tests were run at three sites but problems developed each time which eventually led to abandonment of the proposed site.

A firm selection of such a site was made in January 1969 on the Plaza Trunk in Palos Verdes. The required construction at that site has been detailed and is scheduled to begin in early March 1969. Figures 19 and 20 describe the structures that are proposed for this site.

The equipment proposed for installation at the evolution-corrosion site has been discussed and planned and some components are on hand ready for assembly. It is planned to use a battery powered, timer controlled, atmospheric air pump to pump samples of atmosphere periodically through a silver phosphate absorber tube. An aquarium air pump will be adapted to this application. The actual gathering of data should begin in April or May, 1969.

EVALUATION OF TREATMENT METHODS

It is expected to begin work during the summer of 1969 on evaluation of various methods of treatment to control sulfide in

gravity sewers and siphons.

Specific tests will be devised to evaluate various regimens of continuous feed and shock dosing with various chemicals.

Much of this testing is not yet detailed, but to give an idea of the procedure planned we have included a description of a "Field Test Procedure for Shock Dosing with NaOH for Sulfide Control" in the Appendix.

EFFECT OF UPSTREAM SLUDGE DISCHARGES ON SEWERS

To evaluate this effect it is now planned to:

1. Make a series of bottle tests to measure sulfide production potential in mixtures of various amounts of sludge in sewage.

2. Make a series of tests using the Warburg BOD apparatus to ascertain the rate at which the Biochemical Oxygen Demand of sludge-sewage mixture is exerted.

3. Make field survey during the summer season of the sulfide buildup behavior of sewers downstream of Whittier Narrows treatment plant with and without sludge discharge.

The field procedures for Items 1 and 2 above are shown in the Appendix.

Item 3 above has not yet been detailed, but plans will be laid so that the work can proceed, beginning about July 1, 1969.

APPENDIX A

BASIC RESEARCH ON SULFIDE OCCURRENCE AND CONTROL IN SEWAGE COLLECTION SYSTEMS

RESEARCH PLAN

OUTLINE

I GENERAL OBSERVATIONS ON THE DEVELOPMENT OF THE RESEARCH PLAN

II DESCRIPTION OF PROPOSED WORK

A. Evaluation of Variables Affecting Balance Between Sulfide Generation and In-Stream Oxidation of Sulfide in Free Flowing Sewers

1. List of Variables
2. Proposed Field Tests
   a) Measurement of sulfide generation
   b) Measurement of oxidation plus evolution
3. Proposed Laboratory Tests
   a) Filled pipe test apparatus
   b) Additional laboratory work

B. Evaluation of Factors Affecting Sulfide Generation in Filled Pipes

1. Nature of Problem
2. Proposed Force Main Tests
3. Proposed Depressed Sewer Tests
4. Proposed Laboratory Tests
   a) Nutrient effectiveness
   b) Effect of sulfur source compounds

C. Comparison and Evaluation of Treatment Methods

1. Classification of Treatment Methods

2. Proposed Field Tests

a) Continuous dosing in gravity sewers

b) Shock dosing in gravity sewers

c) Air in force mains

D. Evaluation of Effect on Sulfide Buildup of Solids Enrichment by Discharge of Primary Sludge and Waste Activated Sludge from Upstream Water Reclamation

1. Field Tests Proposed

2. Proposed Laboratory Work

E. Correlation of Sulfide Incidence and Corrosion

1. General

2. Proposed Tests

III FIELD WORK

A. Field Sites

1. Classification and Probable Number of Field Test Sites

2. Criteria for Site Selection

B. Field Test Procedures

1. General

2. Field Test Procedures

a) At sulfide buildup sites

b) At force main sites

c) At evolution-corrosion site

d) At oxygen depletion sites

e) At depressed sewer sites

IV LABORATORY WORK

A. Filled Pipe Test Apparatus

1. Measurement of Nutrient Effectiveness

2. Effect of Sulfur Source Compounds on Sulfide Generation

3. Effect of Velocity on Sulfide Generation

B. Other Laboratory Work

1. Ionization Constant of H_2S

2. Effect of Storage on BOD

3. Assessing Reliability of Silver-Silver Sulfide Electrode

V PRELIMINARY WORK PLAN AND TIME TABLE

A. Work Plan

B. Time Table

I GENERAL OBSERVATIONS ON THE DEVELOPMENT OF THE RESEARCH PLAN

The problem of corrosion of pipes in sewage collection systems due to the effect of hydrogen sulfide is of long standing. It has received some attention of researchers since the mid 1930's only.

Preliminary to the preparation of this "Research Plan" a review was made of the most important related prior work that has been done on various facets of the problem. This included reports of work done in the U. S. A., Australia and South Africa. The entire subject was first explored in considerable detail by Dr. R. D. Pomeroy and his published progress report in 1946, provided the first general guide to the conditions that would prevent or permit sulfide build-up in sewers. A significant addition to this early work was published in 1950 by W. J. Davy of Melbourne, Australia. Finally, in more recent years, in both published and unpublished work, Dr. Pomeroy has furthered some of the thinking about the problem and developed a "Z formula" which attempts to further delineate the borderline conditions for sulfide buildup. Parts of the earlier work was based on scant data and/or assumptions which need systematic detailed checking in the field or laboratory before formulas for prediction of sulfide buildup and methods of preventing buildup, or of ameliorating the effects of buildup can be accepted with full confidence.

It is the purpose of this research program to provide that systematic detailed study.

II DESCRIPTION OF THE PROPOSED WORK

A. EVALUATION OF VARIABLES AFFECTING BALANCE BETWEEN SULFIDE GENERATION AND IN-STREAM OXIDATION OF SULFIDE IN FREE FLOWING SEWERS

1. List of Variables. From previous work we think we know most of the variables that affect this balance. In outline form those which affect:

a) Generation of sulfide are:

-- Nutrients, both type and amount may be significant.
-- Source of sulfur both type and amount.
-- Temperature

-- Wetted surface area to support slimes.
-- Sludge deposits
-- Velocity scour

b) Oxidation in the flowing stream are:

-- Surface area
-- Turbulence due to slope and velocity
-- Concentration of oxygen in the air

2. Proposed Field Tests

a) Measurement of sulfide generation can be made independent of oxidation and evolution by adding zinc sulfate to the flow continuously in excess of the amount needed to precipitate the sulfide. When the sulfide is precipitated there is no dissolved sulfide so all in-stream oxidation and evolution to the atmosphere is stopped. Under these conditions the buildup in total sulfide between the two ends of the test reach is the total sulfide generation.

b) Measurement of oxidation plus evolution is accomplished by adding sulfide to the flow at a uniform rate upstream of a test section of sewer. If within the test reach the sulfide concentration increases, then oxidation plus evolution (O+E) is less than generation by the amount of the buildup. If the sulfide concentration decreases, then O+E is greater than generation by the amount of depletion. If generation is measured at the same site by the method described above under nearly identical conditions, then the figures are in hand for estimation of the rate of O+E under the test conditions.

3. Proposed Laboratory Tests

a) Filled pipe test apparatus. A special apparatus has been designed with which tests can be made in the laboratory of the rate of sulfide generation in a filled pipe system with closely controlled environmental conditions. The apparatus is to be used as described below to evaluate the relative strength of different nutrients in supporting sulfide generation and the effect of different sulfur source compounds on sulfide productions.

A flow diagram for the test setup is attached as Figure 1 and the proposed tests are described in more detail elsewhere.

b) Besides the tests using the filled pipe apparatus some additional laboratory work will be undertaken to compare different methods of measuring sewage strength. Such things as one-day BOD, COD will be compared with the standard 5-day BOD. If this is done for nutrients on which sulfide producing capability has been established in the filled pipe tests, significant insights about selection of a test method for sewage strength may emerge.

B. EVALUATION OF FACTORS AFFECTING SULFIDE GENERATION IN FILLED PIPES

1. Nature of the Problem. In a filled pipe there is no water surface exposed to the air and hence no in-stream oxidation. For this reason closed pipes in a sewage collection system can generate large amounts of sulfide and create serious nuisance and hazards downstream.

2. Proposed Force Main Tests. It is proposed to make a series of tests on the sulfide generating capacity of sewage in pump station force mains. The method will be to measure the sulfide buildup under various conditions in the same force main.

3. Proposed Depressed Sewer Tests. A similar series will be run on some depressed sewers where full pipe conditions exist.

4. Proposed Laboratory Tests.

a) Nutrient effectiveness can be measured by bringing the filled pipe apparatus to an equilibrium condition with a constant feed of a particular nutrient. Insofar as possible all other variables will be held constant while the type of nutrient is varied. This should lead to a figure of sulfide production capacity in lb/hr. per square ft. of interior pipe surface at constant nutrient dosage.

b) A test has been devised to measure the effect of different sulfur source compounds on sulfide generation.

C. COMPARISON AND EVALUATION OF TREATMENT METHODS

1. Classification of Treatment Methods. A fairly complete classification of treatment methods is shown in Table 1 below. For practical reasons it is necessary to select from this list those treatment method most likely to be practical and most economical and to carry forward a a more detailed study of these particular methods.

TABLE 1

CLASSIFICATION OF TREATMENT METHODS

TREATMENT METHODS THAT:	
1. Curtail Generation	
Nutrient Control:	Dilution Pretreatment oxidation In-stream oxidation Exclusion of high strength wastes
Slime Removal:	Physical cleaning sterilization: Chlorine Metals Chlorinated hydrocarbons Lime Sodium hydroxide
Temperature Control:	Dilution Exclusion of heated wastes
Instream Source of Oxygen:	Nitrate
2. Increase Oxidation	
Increase Oxygen Uptake:	Velocity control Oxygen addition for atmosphere enrichment
In-stream Oxidizing Agents:	Chlorine Air Chromate Other oxidizing agents
3. Other Methods	
Precipitate Dissolved Sulfide with Heavy Metals:	Zinc Iron Copper
Curtail Evolution:	pH control Avoid turbulence
Curtail Atmospheric Oxidation:	Ventilation to dry walls Sterilization to kill bacteria
Neutralize H_2SO_4:	Lime dust Ammonia

NEXT STEPS

About a third to a half of this first project year was occupied with preliminary tasks of planning, assembling equipment, training personnel and refining techniques. It is to be expected that the next year will be markedly more fruitful in gathering of reliable relevant data.

It seems clear that this data gathering period ought to extend through the high temperature summer period of 1970 in order to get enough information for reliable conclusions.

Active analysis and collation of the field data have begun. This will continue and will occupy more time through the remainder of the project than heretofore. It appears though that preparation of a final report could be undertaken most expeditiously after the conclusion of a field data gathering period. This suggests a report preparation period beginning about December 1970.

PROJECT ORGANIZATION

PERSONNEL

The project is under the direct supervision of Mr. Jack Livingston, Project Engineer. The three-man field crew from March to December, 1968, consisted of William Parsonson, Richard Boyington, and Jon Boss. In December, 1968, Mr. Parsonson transferred off the project, and in January, 1969, Mr. Glen Schnoor was hired. The field crew was placed under the supervision of Mr. Boyington in December of 1968.

The consulting firm of Pomeroy, Johnston and Bailey, Civil and Chemical Engineers, provides technical services under a purchase order issued by the Sanitation Districts. Dr. Richard Pomeroy worked as needed about three days per month during the year. Mr. Harry Bailey worked about three days per week on the project. Over-all supervision is provided by Mr. Charles Carry, Division Engineer for Research and Development for the Sanitation Districts.

Mr. John D. Parkhurst, Chief Engineer and General Manager of the Sanitation Districts, is Project Director. Regular staff meetings were held about monthly and were attended by Messrs. Livingston, Pomeroy, Bailey, Carry, and Mr. Frank Dryden, Deputy Assistant Chief Engineer, who is responsible for all field sewerage activities of the Sanitation Districts. Mr. Parsonson attended some of the staff meetings during an initial organization period.

The pattern of air addition, i.e., continuous, intermittent fast or slow will also influence sulfide control results using injected air.

D. EVALUATION OF EFFECT ON SULFIDE BUILDUP OF SOLIDS ENRICHMENT BY DISCHARGE OF PRIMARY SLUDGE AND WASTE ACTIVATED SLUDGE FROM UPSTREAM WATER RECLAMATION PLANTS.

1. Field Tests Proposed. An initial step would be to survey sulfide build-up conditions at key points in the sewer system downstream of Whittier Narrows Water Reclamation Plant. Such a survey would be attempted with and without sludge discharge within the ability of the plant to vary that discharge.

2. Proposed Laboratory Work. Determination of oxygen demand will be made in bottles or possibly by use of Warburg apparatus. Of particular interest is the rate at which the biochemical oxygen demand is exerted by the sludge to be wasted. Such a determination will be made for primary sludge, waste activated sludge and for a typical mixture using sludge from the Whittier Narrows Activated Sludge Plant.

E. CORRELATION OF SULFIDE INCIDENCE AND CORROSION

1. General. There is some uncertainty about how much hydrogen sulfide can be tolerated in the sewage flow and in the sewer atmosphere without danger of significant corrosion. Evidence in fact indicates that it may be different in different situations, particularly due to variations in turbulence.

2. Proposed Tests. It is proposed to measure corrosion by a sensitive chemical measurement of corrosion products as they accumulate on a test section of pipe wall. By this method the corrosion rate can be established with great accuracy long before the physical effects of corrosion can be observed. On a test section of pipe wall, if all corrosion products for a test period are removed and analyzed for calcium and sulfate, an accurate estimate can be made of the amount of sulfuric acid formed by oxidation of H_2S on the pipe wall and of the amount of concrete affected by the corrosion. This corrosion rate will then be correlated with: the quantity of HS^- in the sewage, the quantity of H_2S in the atmosphere and the location of the test point in relation to turbulence points in the sewage flow.

III FIELD WORK

A. FIELD SITES

1. Classification and Possible Number of Field Test Sites

Type of Site	Tests to be Run	Possible No.
Buildup in sewers	Generation and buildup or depletion	25
Buildup in siphons	Generation	5
Force Mains	Buildup and air injection	10
Q_2 Depletion	O_2 Depletion & HS^- generation & buildup or depletion	3
Evolution-Corrosion	H_2SO_4 formation and pipe material corrosion	1
Treatment methods	Evaluation of treatment methods	10

2. Criteria for Selection of Field Test Sites

a) Buildup in sewers site

- -- 500 feet or more with no contributions
- -- Cover range of slope and diameter. Current plan is to select sewers 10", 18", 27", 36", 48", and 60" in diameter.
- -- Uniform slope and size within reach

b) Buildup in siphons Site

- -- Range of slope and size
- -- Preferably single barrel
- -- As long as possible

c) Force Mains Site

- -- Continuous upgrade profile from pump to discharge
- -- Range of sizes
- -- Preferably stations with existing air injection equipment
- -- Sites should preferably permit air injection to be turned off for one week plus without creating an odor nuisance.

d) Oxygen depletion site

- -- Long reach with no contribution
- -- Uniform slope and size in that reach
- -- Sulfide present most of the time

e) Evolution - Corrosion Site

-- Site with sulfide present most of the time.
-- Off street, no paving, no utilities
-- 10", 12", or 15" sewer running less than half full

f) Treatment methods site

-- Site with sulfide present much of the time
-- 500 feet or more with no contribution
-- Uniform slope and size within the reach
-- Smaller pipe sizes more practical

B. FIELD TEST PROCEDURES

1. General. It is highly desirable to obtain a maximum of data from every site. Sometimes a site will qualify within several of the classes listed above. It will also be possible, sometimes to test at several levels for a given variable at a single site. Thus, several test runs may be desirable at a particular spot. Some variables that can be controlled to a degree are as follows:

a) Sewage strength can be normal, higher by enrichment, or lower by dilution.

b) Quantity of flow can be low as at night or higher as at peak flow. In a few sites it will be possible to divert flow in or out of the test sewer due to the presence of diversion manholes upstream. At these points data can be gathered at several values of Q with other data essentially constant.

c) Temperature can be varied by checking the same site at two different times of the year.

2. Field Test Procedures. The accounts which follow below are explanatory in nature and are supplemented by specific Field Procedures in the accompanying tables where those procedures have been developed.

a) At sulfide buildup sites. The Table below shows the procedure as revised to May 20, 1967.

TABLE 2

PROCEDURE AT SULFIDE BUILDUP SITE

1. Check Out Test Site in Advance

   a) Open manhole and check for laterals.

   b) On 10", 18" and 27" lines install flow measuring weir or slab at the "weir manhole" shown on the drawings.

   c) Make one preliminary measurement of transit time using fluorescein dye.

   d) Check rim to invert measurements for all manholes within the test reach and tie to B.M., if possible.

2. Preliminary to Test Run at the Site

   a) Check dissolved sulfide at upper and lower end of test reach.

   b) If dissolved sulfide is below 0.1 ppm at either end then start feed of Na_2S solution at chemical feed manhole shown on the drawing.

      Increase gradually until dissolved sulfide is 1 ppm or more at the top and greater than 0.2 ppm at lower end.

3. Sulfide Buildup-Deletion Test Run
   (1 hour duration)

   a) On 10", 18" and 27" at chemical feed and weir manhole

      At 10 minute intervals:

      Measure depth at weir
      Measure temperature
      Measure pH
      Take samples for BOD - Combine into a single one hour composite BOD sample.

(Continued)

Table 2 (Continued)
Procedure at Sulfide Buildup Site

b) At Upper End Manhole (all sizes)

At 10 minute intervals:

Measure dissolved sulfide
Measure depth rim to W.S.
Add dye for velocity checks
Use walkie talkie to start watches at one or two measuring sites downstream at the time of dye addition

c) At Lower End Manhole (all sizes)

At 10 minute intervals:

Measure dissolved sulfide
Measure depth rim to W.S.
Note time of dye passage

d) On 36", 48" and 60" - set up at a manhole intermediate between upper end and lower end in addition to upper and lower manhole setups.

At 10 minute intervals:

Measure depth rim to water surface
Note time of dye passage
Measure temperature
Measure pH
Take samples for single one hour composite BOD

4. Sulfide Generation Test Run (1 hour duration)

a) Discontinue sulfide feed and begin feeding zinc sulfate at chemical feed manhole.

b) Repeat all measurements as shown in 1 through 4 above except measure total sulfide instead of dissolved sulfide.

5. Miscellaneous Tests

a) On some runs it will be desirable to run dissolved oxygen at both upper and lower end manholes. This can be done by chemical or potentiometric means.

b) At force main sites. Previous work on force mains has shown that air injection induces sloughing of slimes thereby reducing the generation rate. Test procedures need to take that into account. A general description of the tests is as follows:

-- Determine the initial sulfide buildup pattern by measurements of influent and discharge over several hours with no treatment.

-- Start at a low injection rate and increase stepwise but at each step level continue for 24 hours to allow completion of sloughing of slimes at that rate and establish new generation rate.

-- After 24 hours at a particular air injection rate buildup will be noted.

-- Repeat at new higher injection rate.

The force main tests will make use of the existing installed air compressors but will feed through a portable air control receiver that has been designed and built for the purpose. This air control unit is shown in Figure 2. The detailed test procedure for force mains is shown in Table 3 below.

TABLE 3 FORCE MAIN TEST PROCEDURE

A. Advance Preparation

1. Check out accessibility of sampling spots at pump station and at the end of force main.
2. Turn off air and discontinue all other treatment 2 weeks in advance of beginning of test to permit maximum buildup.
3. Install air control assembly as soon as possible after air is turned off ready for initial test.
4. Check pump capacity by wet well measurements.

B. Initial Buildup Test (Duration about 4 hours)

1. At Pump Station End:
   a) Measure total sulfide 30 seconds after pump comes on and at one minute intervals thereafter during the pump "on time".
   b) Measure dissolved oxygen, temperature and pH at one-half hour intervals.

c) Take a sample for BOD during each pump "on time". Composite these for a single BOD determination for each half hour of flow during the test.

2. At Effluent end of Force Main

a) Measure total sulfide 30 seconds after pump comes on and at one minute intervals thereafter during pump "on time".

b) Composite from "on time" samples a single sample for settleable solids for the duration of the test.

C. Buildup with Air Injection

1. Set air injection rate at 2.0 SCFM and measure transit time for air by noting time of start and time of arrival at end of force main.

2. Take sample at effluent end of force main for settleable solid approximately one half hour after air start -up time.

3. Return daily to sample force main effluent for settleable solids and total sulfides, one sample only when pump is on.

4. After sulfide buildup appears to be steady (2 or 3 days?) then monitor new sulfide buildup pattern by repeating B 1, and 2, above.

5. Reset air to 4 SCFM and repeat C 1 through 4 above.

6. Increase air injection rate according to the above pattern until no sulfide buildup occurs.

c) At evolution-corrosion site. It will be necessary to monitor the dissolved sulfide content of the sewage and the H_2S content of the atmosphere at this site over an extended period of time.

This can be done manually by running 24-hour tests four times per year with periodic checking in between. It would, of course, be desirable, if possible, to automate this monitoring. Since what is needed and desired is an integrated volume of the average sulfide content with no requirement for knowledge of the actual concentration at any particular time, this automation may be possible without excessive expense. Work is under way on this.

A description of the test installation is as follows:
-- At test points a 3" piece of the top half of the pipe is cut out springline to springline.

-- A test section of new pipe is cut to fit and placed in this slot at each test point.

-- Test points are proposed along a straight run of pipe, at a point of turbulence, 10 diameters upstream of a point of turbulence, and 10, 25, 50, and 100 diameters downstream of the point of turbulence.

-- It will probably be necessary to build a series of manholes over the test line to maintain access to those test points.

d) At oxygen depletion sites

-- In a long reach of sewer the manhole atmosphere will be isolated from the sewer atmosphere by use of plastic membranes at the shelf level. Oxygen content of the atmosphere and other variables are then measured at the top and bottom of the reach for a one-hour period.

-- The procedure is much the same as outlined above for a Sulfide Buildup Site.

-- Prior to the buildup and generation tests run an oxygen depletion test with procedure as shown in the table.

TABLE 4 OXYGEN DEPLETION TEST (1 hour duration)

1. Install plastic sheets at shelf level in all intermediate manholes.
2. Monitor O_2 in the atmosphere at 10 minute intervals at the bottom manhole for 1 hour.
3. During the run measure flow at the PB meter or weir at 10-minute intervals.
4. Measure temperature (lower M.H.) and dissolved sulfide (upper & lower manholes) at 10-minute intervals.
5. Take a proportional composite BOD sample for the one hour test (upper manhole)

e) At depressed sewer sites

A proposed procedure is shown in the following table.

TABLE 5 PROCEDURE AT DEPRESSED SEWER SITE

A. Check Out Test Site in Advance

1. Check both ends of siphon for accessibility
2. Using salt or radioactive gold determine Q and full pipe n for the siphon
3. Check relative rim elevations of access manholes at both ends of siphon

B. Sulfide Buildup Test Run (1 hour duration)

1. At Upper MH at 10 Minute Intervals
   a) Measure dissolved sulfide
   b) Measure depth from rim to water surface
   c) Take samples for single one hour composite for BOD
   d) Measure dissolved oxygen
2. At Lower End MH at 10 Minute Intervals
   a) Measure dissolved sulfide
   b) Measure depth from rim to water surface
   c) Measure temperature
   d) Measure pH

IV LABORATORY WORK

A. FILLED PIPE TEST APPARATUS

1. Measurement of Nutrient Effectiveness

a) It is proposed initially to test sucrose, glucose, acetic acid, citric acid, gelatin, peptone, emulsified fat.

b) Set up apparatus for 300 ppm nutrient feed rate, approximately 1 hour turnover rate, and 1 fps recirculation rate.

c) Seed the apparatus with sewage and precondition by running with the selected nutrient for about 24 hours. Operation may be intermittent during this period.

d) Make test run by steady operation at test conditions until sulfide content of the constant rate overflow is steady.

e) Change nutrient and repeat.

2. Effect of Sulfur Source Compounds on Sulfide Generation. Sulfate is nearly always present in sewage flow and part of the time at least it is the sulfur source compound from which sulfide is generated. However, in some sewages other sulfur compounds may be present that can be more readily used by bacteria than the sulfate ion, as a source of sulfur.

Using the "filled pipe apparatus" the ability of slimes to utilize various sulfur compounds as a sulfur source can be directly controlled by using a feed with and without sulfate and other compoundsof sulfur.

3. Effect of Velocity on Sulfide Generation. Initial nutrient experiments were run at 1 fps recirculation velocity. Using a nutrient previously tested, say, sucrose, repeat the nutrient test with successively higher recirculation rates, 1, 2, 3, 4, 5 fps, etc. When the liquid velocity begins to scour off slimes this should appear in a lower sulfide generation rate in the test apparatus.

B. OTHER LABORATORY WORK

1. Ionization Constant of H_2S. Recent work, not on this project, has given reason to believe that the commonly accepted values for the ionization constant of H_2S and for the effect of ion strength and temperature thereon are not very accurate. It is planned, therefore, to determine this constant with some care so that a reliable figure will be available for calculation of the relationship of dissolved and atmospheric sulfides.

2. Effect of Storage on BOD. An experiment has been devised to determine what effect storing samples with or without refrigeration, and in full or part full bottles, has on the Biochemical Oxygen Demand of the samples. This test will serve to define the limits that must be placed on handling samples if we are to get accurate BOD results.

3. Assessing Reliability of Silver-Silver Sulfide Electrode. It is relatively easy to use the Ag-AgS electrode for qualitative determination of the presence or absence of dissolved sulfide. A more complicated but still practical use for quantitative sulfide determination has been conceived but considerable work would be required to ensure a trouble-free setup. The use

of this item of equipment has been seriously considered but it is still not clear that it really will be needed. The decision of whether or not to spend time on this will be deferred until later in the project when further field experience of the project will facilitate the decision.

V PRELIMINARY WORK PLAN AND TIME TABLE

	Date Start	Date End
A. REVIEW AND EVALUATION OF PRIOR WORK		
1. Work of Pomeroy, Parker, Laughlin, Davy, Heukelekian, etc.	3/ 1/68	3/31/68
B. REVIEW & EVALUATION OF DATA (now on hand in LACSD Files)		
1. Independent study of data	4/ 1/68	4/30/68
2. Conferences w/LACSD personnel re their evaluation of the data		
C. PREPARE RESEARCH PLAN		
1. Description of Field Tests	3/ 1/68	7/ 1/68
2. Criteria for field site selection		
3. Description of laboratory tests		
4. Design or selection of required equipment		
5. Timetable for first year of program		
D. FIELD TEST EQUIPMENT		
1. Write specifications and descriptions of needed vehicles, buildings and other field equipment	3/15/68	8/15/68
2. Order and purchase equipment		
3. Construct building		

	Date Start	Date End
E. LABORATORY TEST EQUIPMENT		
1. Write specifications and descriptions of needed equipment	3/15/68	8/15/68
2. Order and purchase equipment		
3. Assemble equipment		
F. SELECT FIELD TEST SITES		
1. Examine office information on sites	4/ 1/68	7/31/68
2. Make tentative site selections		
3. Review proposed sites with field personnel		
4. Make field inspection as necessary		
5. Make final selection of sites		

G. GATHER FIELD DATA

A single test run will involve one to two hours of continuous testing plus time for travel and setup. We have therefore assumed that each test run will take one half day besides the preliminary setup time at each site which is also estimated at one-half day. In general, we believe a minimum goal of five field tests per week should be set with the hope that with experience this might be exceeded.

	No. of Sites	Number ½ da.runs per site	Total ½ da.runs	Weeks Required	Dates Start	Dates End
A. Generation - Buildup Sites on Sewers	25					
Setup		1	25)	55		
Test runs		10	250)			
B. Siphon Sites	5					
Setup		1	5)	3		
Test runs		2	10)			
C. Oxygen Depletion Sites	3					
Setup		2	6)	5		
Test runs		6	18)			
D. Force Mains	10					
Setup		2	20)	14		
Initial Buildup		2	20)			
Buildup 4 air rates		6	30)			
E. Evolution Site	1					
Setup		4	4)	$2\frac{1}{2}$		
Monitor sulfides and R & R Test Sections		8	8)			
F. Effect of M.A.S.	1					
Survey w/sludge		6	6)	$2\frac{1}{2}$		
Survey w/o sludge		6	6)			
G. Treatment Methods	5					
Setup		1	5)	10		
Continuous dosing tests		6	30)			
Shock dosing tests		3	15)			
		TOTAL WEEKS		92	8/1/68	8/31/70*

* 92 weeks runs only to June 1970 but work time should include summer months of 1970 for best results

H. GATHER LABORATORY DATA

Note: Filled pipe generation tests should be possible at rate of about three per week.

	No. of Tests	Weeks Required	Dates Start	Dates End
1. Nutrient Effectiveness Tests	20)	12	7/1/68	9/30/68
2. Sulfur Source Compounds	6)			
3. Sludge as Nutrient	10)			
4. Ionization Constant H_2S		2	5/15/68	6/ 1/68
5. BOD Storage		2	5/1/68	5/15/68
6. Miscellaneous Laboratory Experiments		10		

Routine laboratory work in conjunction with field tests will be done either at PJB or at Compton by other staff than the field crew so scheduling is not necessary. The work will be done as needed.

I. PREPARE WRITTEN REPORT

Some of the work of correlating data will be done as the work proceeds but 6 months have been set aside at the end of the 3-year period for report preparation. 9/1/70 2/28/71

Los Angeles Co. Sanitation Distr.

Sulfide Research Project

SUMMARY DATA SHEETS.

Build up - Depletion Sites

Appendix B
SHEET No. 1
Rev. to 2/22/69

Date	Site	Length feet	Length meters	Slope pipe %	Slope W.S. %	Hour from	Hour To	No of tests	Velocity trans time	Velocity fps	Velocity m/sec	Feed Info. Chemical Added	mg/l as Zn
1963													
7/26	18D	2901	910	0.12	.112	11:35	12:30	7	39:30	1.40	.427	Na_2S	
7/26	18D	2901	910	0.12	.113	12:39	13:30	5	37:05	1.30	.396	$ZnSO_4$	—
7/30	21D	1630	497	.098	.116	11:00	12:10	7	16:03	1.69	.515	Na_2S	
7/30	27D	1630	497	.098	.116	12:27	12:30	6	16:25	1.66	.506	$ZnSO_4$	—
8/5	36H	1975	602	.498	.528	11:20	12:10	5	9:50	6.85	2.09	Na_2S	
8/5	36H	1975	602	.498	.528	13:02	14:05	6	9:52	6.76	2.06	Na_2S	
9/5	36H	1975	602	.498	.518	13:05	14:40	4	9:53	6.76	2.06	$ZnSO_4$	—
8/13	27D	1630	497	.098	.117	12:45	13:40	7	16:37	1.63	.498	Na_2S	
8/13	27D	1630	497	.098	.117	14:00	14:30	3	16:07	1.69	.515	$ZnSO_4$	—
8/20	18E	907	277	.160	—	12:25	13:15	6	4:26	3.5	1.07	Na_2S	
8/20	18B	907	277	.160	—	13:35	14:05	3	5:01	3.01	0.92	$ZnSO_4$	—
8/21	18C	802	245	.1485	.161	12:45	13:50	7	4:02	3.31	1.01	Na_2S	
8/21	18C	802	245	.1485	.161	19:20	19:40	3	4:06	3.26	.99	$ZnSO_4$	—
8/23	27C	1613	492	.202	—	12:50	13:35	5	7:39	3.51	1.07	Na_2S	
8/23	27C	1613	492	.202	—	13:55	14:35	3	7:39	3.51	1.07	$ZnSO_4$	
8/27	21CG	2749	839	.163	—	13:55	14:30	4	17:27	2.63	.803	Na_2S	
8/27	27JJ	2749	839	.163	—	14:55	15:32	4	17:27	2.63	.803	$ZnSO_4$	
8/30	21CR	2616	797	.083	—	11:10	13:05	6	18:40	2.36	.720	None	
8/30	21CR	2616	797	.083	—	12:15	13:15	6	18:40	2.36	.720	$ZnSO_4$	
9/5	18F	1489	454	.375	—	12:10	13:10	7	6:50	3.64	1.11	Na_2S	
9/5	18F	1489	454	.375	—	13:10	14:10	5	7:07	3.48	1.06	$ZnSO_4$	—
9/6	18J	2440	744	.978	.978	12:45	13:25	5	6:37	6.15	1.875	Na_2S	
9/6	18J	2440	744	.978	.978	13:45	14:10	3	6:45	6.03	1.84	$ZnSO_4$	—
9/11	18H	3023	924	.778	.810	11:50	12:30	5	8:40	5.83	1.78	Na_2S	
9/11	18H	3023	924	.778	.810	13:00	13:40	5	8:53	5.73	1.81	$ZnSO_4$	
9/20	36K	1908	429	.696	—	13:05	13:55	6	3:45	6.23	1.90	Na_2S	
9/20	36K	1908	429	.696	—	14:35	15:15	5	3:49	6.80	1.75	$ZnSO_4$	
9/25	48A	1517	463	.047	.025	11:40	12:40	5	11:30	2.20	.671	Na_2S	
9/25	48A	1517	463	.047	.025	12:50	13:55	6	11:30	2.20	.671	$ZnSO_4$	—
9/27	48B	1359	415	.0794	.0694	11:20	12:20	5	10:30	2.16	.660	Na_2S	
9/27	48E	1359	415	.0794	.0694	13:20	14:10	6	10:30	2.16	.660	$ZnSO_4$	—
10/2	36C	2398	732	.155	.161	12:45	13:20	5	22:28	1.78	.544	Na_2S	
10/2	36C	2398	732	.155	.161	13:35	14:20	6	22:28	1.78	.544	$ZnSO_4$	—
10/7	18M	5537	1687	.290	—	11:10	11:30	3	24:26	3.70	1.13	None	
10/7	18M	5537	1687	.290	—	11:40	12:10	4	24:26	3.70	1.13	None	
10/9	24B	5894	1800	.105	—	11:20	12:30	7	48:26	2.02	.616	Na_2S	
10/9	24B	5894	1800	.105	—	13:15	14:15	7	48:26	2.02	.616	$ZnSO_4$	102
10/15	24B	5894	1800	.105	—	11:10	12:10	7	46:30	2.11	.644	Na_2S	
10/15	24B	5894	1800	.105	—	13:00	13:40	5	46:30	2.11	.644	$ZnSO_4$	—

Date	Total Sulfide UM mg/l	Total Sulfide LM mg/l	Total Sulfide Average ΔS mg/l	Dis. Sulfide UM mg/l	Dis. Sulfide LM mg/l	Dis. Sulfide Average ΔS mg/l	Diss. Oxygen UM mg/l	Diss. Oxygen LM mg/l	Diss. Oxygen Aver. ΔDO mg/l	Temp °C	pH	Comp. BOD 1da	Comp. BOD 5da	COD	5BOD	Flow d/D	Flow cfs	Flow gpm
7/26	1.2	0.63	-.57	—	—	—	5.1	2.3	-2.8	27.2	8.0	—	128	—	208	.37	.91	253
7/26	0.01	.11	+.11	—	—	—	5.6	3.2	-2.4	27.9	7.3	—	128	—	226	.33	.74	210
7/30	0.80	0.76	-.04	—	—	—	0.35	0.24	-.11	25.6		—	193	—	209	.33	.97	553
7/30	Tr	0.16	+.15	—	—	—	0.45	0.33	-.07	25.6		—	178	—	260	.324	.86	526
8/5	0.38	0.29	-.09	—	—	—	0.69	0.77	+.08	26.7	—	—	172	—	270	.426	.98	526
8/5	0.5	0.34	+.16	—	—	—	.69	.64	-.05	27.2	—	—	152	—	247	.324	.169	479
8/13	0.1	0.1	0	—	—	—	.69	.81	+.12	26.7	—	—	139	—	204	.314	.160	454
8/13	0.63	.59	-.04	—	—	—	.20	.19	-.01	26.2	—	—	—	—	—	.282	.232	657
8/13	.95	0.10	+.05	—	—	—	.16	.21	+.05	26.7	—	—	—	—	—	.302	.207	587
8/20	0.5	0.2	-.3	.02	.05	+.03	.93	1.34	+.41	26.2	7.9	72	160	—	243	.27	.644	182
8/20	.13	.12	-.01	0.0	.12	+.12	.41	1.1	+.69	26.7	7.7	73	151	—	238	.293	.512	145
8/21	1.0	.95	-.05	.56	.068	-.12	.97	1.5	+.53	26.7	8.1	79	170	—	267	.72	4.25	123
8/21	0.11	0.02	-.09	.01	.01	0	.36	1.35	+.99	26.2	7.2	65	138	—	210	.61	.42	179
8/23	1.0	.92	-.08	0.4	0.5	+.1	.41	.54	+.13	27.3	8.0	65	174	—	295	.60	7.95	222
8/23	0.0	.03	+.03	0	0	0	.50	.76	+.26	27.8	8.0	59	169	—	236	.58	7.90	210
8/27	1.3	1.2	-.1	0.7	.55	-.15	.39	.70	+.31	26.2	7.8	58	166	—	252	.28	3.60	12
8/27	.24	.07	-.17	—	—	—	.43	.62	+.19	26.5	7.6	68	168	—	264	.26	3.33	94
8/30	.48	.64	+.16	.36	.20	-.16	.77	.74	-.03	27.8	9.0	—	—	—	—	—	2.05	81
8/30	.52	.76	+.24	.07	0	-.07	1.25	.91	-.34	27.8	9.0	131	151	—	256	—	1.99	56.3
9/5	1.73	1.56	-.17	.27	.68	+.19	1.9	1.5	-.4	27.8	9.3	91	119	375	202	.61	354	100
9/5	.01	.01	0	—	—	—	3.05	2.16	+.11	27.8	8.2	126	147	472	249	.58	349	99
9/6	1.04	.82	-.22	0.5	0.4	-.1	1.85	1.20	-.65	27.8	8.2	25	126	402	214	.50	5.44	154
9/6	0.0	0.03	+.03	—	—	—	2.2	1.9	-.3	27.8	8.1	35	113	382	192	.47	7.92	191
9/11	1.36	1.42	+.06	.90	.44	-.46	1.36	0.97	-.39	27.8	8.1	34	137	406	232	—	5.91	221
9/11	0.0	0.0	-0-	0.0	0.0	0.0	1.51	1.47	-.04	27.8	7.9	68	178	500	302	—	7.28	155
9/20	0.90	.95	+.05	.47	.53	+.04	1.07	.40	-.667	26.2	7.3	66	154	366	203	.31	1.63	334
9/20	.16	.21	+.05	0.0	0.0	0	1.0	.68	-.32	26.6	7.2	98	164	413	254	.30	1.63	320
9/25	1.16	1.12	-.06	.16	.22	+.06	2.3	1.6	-.7	29.7	8.1	—	379	264	728	.54	15.12	435
9/25	.23	.19	-.04	0	0	0	2.0	1.1	-.9	30.0	7.5	—	453	335	890	.53	14.25	423
9/27	.74	.90	+.16	.22	.32	+.10	.74	1.23	+.35	28.4	7.8	—	441	303	776	.63	17.9	526
9/27	.14	.25	+.01	0	0	0	.67	1.43	+.76	28.9	7.0	—	452	131	835	.63	18.1	512
10/2	1.76	1.16	-.60	.51	.15	-.36	1.13	.88	-.25	26.7	7.3	554	1383	3544	2180	.53	6.72	190
10/2	.76	.41	+.25	0	—	—	2.3	1.8	-.5	27.2	9.4	675	1579	3560	2560	.54	6.87	195
10/7	2.46	1.27	-1.19	0	0	0	1.29	1.24	-.05	26.2	7.6	124	241	944	346	.52	2.13	60.3
10/7	.60	0.21	-0.39	0	0	0	1.26	2.37	+1.11	26.7	7.6	124	241	940	379	.74	2.51	709
10/9	1.36	1.11	-.26	.74	.64	-.10	1.40	.37	-1.03	24.4	7.7	—	—	644	—	.63	2.57	72.9
10/9	0.90	.73	+.33	.03	.21	+.18	1.86	1.1	-.76	24.4	7.7	—	—	524	—	.63	2.50	70.9
10/15	.97	.67	-.30	.37	.35	-.02	2.2	0.8	-1.4	24.4	8.0	88	171	652	230	.70	29	82.0
10/15	.30	.66	+.36	0	.13	+.13	2.7	2.5	-.2	24.4	8.1	77	201	620	270	.67	2.52	713

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Appendix B Sht 1.

Los Angeles County Sanitation District — SUMMARY DATA SHEETS — Appendix B SHEET No. 2

Sulfide Research Project — Build up-Depletion Sites

Date	Sht	Length feet	Length miles	Slope %	WS %	Hours From	Hours To:	No. of Jars	Velocity ft/min	Velocity fps	Velocity ft/sec	Feed Infl. Chemical Added	Zn mg/l	Total S Um mg/l	Total S Lm mg/l	Total S ΔS mg/l	Diss. Sulfide Um mg/l	Diss. Sulfide Lm mg/l	Diss. Sulfide ΔS mg/l	Diss. Oxygen Um mg/l	Diss. Oxygen Lm mg/l	Diss. Oxygen ΔDO mg/l	Temp °C	pH	Comp Pipe Inlet	Comp Pipe Outlet	COD	-	FLOW d/D	FLOW cfs	FLOW ft/sec
1968																															
10/16	60C	5512	16801	.0536	.0589	12:00	12:50	6	22.00	3.28	1.00	Na_2S		1.10	1.12	+.02	0.3	0.23	-.07	0.79	0.63	-0.11	25.5	7.7	107	263	748	382	.534	38.5	4.90
10/16	60B	5512	16801	.0536	.0576	13:50	14:20	7	28.30	3.22	.981	$Zn SO_4 80$		0.31	0.42	+.05	0.0	0.0	0.0	0.29	0.68	+.39	26.5	7.6	108	279	736	405	.555	36.2	10.25
10/17	24B	5893	17962	.122	—	12:00	12:50	6	48.00	2.05	.625	Na_2S		1.66	2.08	+.42	1.30	1.55	+.25	1.7	.86	-.84	25.4	7.7	90	234	640	315	.67	24.0	6.8
10/17	24B	5893	17962	.122	—	13:40	14:40	7	48.00	2.05	.625	$Zn SO_4 24.8$		0.49	1.06	+.57	0.0	0.0	0.0	1.7	2.09	+.39	24.4	7.7	83	189	1016	254	.665	22.5	6.37
10/24	60B	5512	16801	.0536	.0488	10:45	11:45	6	28.00	3.28	1.00	None		0.42	0.49	+.21	0.03	0.21	+.18	.22	.15	-.07	25.5	7.8	48	212	660	308	.536	32.4	10.6
10/24	60B	5512	16801	.0536	.0588	12:05	12:25	6	28.00	3.28	1.00	$Zn SO_4$ 2.1		0.76	0.78	+.02	0.0	0.09	0.09	.29	.10	-.19	25.5	7.8	49	215	963	312	"	32.4	10.2
10/25	24B	5893	17962	.0536	—	9:20	10:30	7	47.20	2.07	.631	None		0.19	0.59	+.40	0.03	0.18	+.15	1.71	.93	-1.28	23.9	8.3	14	177	580		.615	2.55	72.2
10/25	24B	5893	17962	.0536	—	10:45	11:45	6	48.00	2.05	.625	$Zn SO_4$ 14.1		0.20	0.84	+.64	0.0	0.13	+.13	1.90	1.03	-.87	24.4	8.3	15	176	628	210	.660	2.44	67.4
10/25	24B	5893	17962	.0536	—	12:50	13:50	7	48.05	2.05	.625	Na_2S		1.50	1.41	-.09	0.9	0.9	0.0	2.19	1.33	-1.86	24.4	8.1	33	160	508	216	.664	2.30	65.1
10/30	18D	2901	8842	.120	.114	10:50	11:40	6	37	1.32	.402	Na_2S		1.25	0.57	-.71	0.93	0.25	-.68	2.11	0.77	-1.34	24.7	8.0	30	103	333	161	.317	.62	17.6
10/30	18D	2901	8842	.120	.114	13:20	14:09	7	40	1.22	.372	$Zn SO_4$ 108		0.52	0.60	+.84	0.0	0.0	0.0	3.60	3.06	-.54	27.2	7.8	50	141	562	228	.296	.55	15.6
10/31	18D	2901	8842	.120	.114	10:20	11:20	7	34	1.42	.433	Na_2S		1.62	.86	-.76	1.22	0.53	0.69	3.3	1.32	-1.98	27.2	8.1	47	104	544	169	.34	.63	18.4
10/31	18D	2901	8842	.120	.115	12:10	13:10	7	40	1.21	.369	$Zn SO_4$ 106		0.0	.65	+.65	0.0	0.0	0.0	3.9	4.0	+.1	26.7	8.0	49	118	654	185	.296	.42	14.7
11/8	21R	2616	7974	.084	.080	11:00	11:50	6	18.25	2.38	.725	None		.04	.07	+.03	0.0	0.0	0	.67	.79	+.12	26.2	8.2	96	132	724	198	.446	2.30	65.1
11/8	21R	2616	7974	.084	.080	12:50	13:50	7	19.00	2.31	.704	$Zn SO_4$ 9.1		.04	.04	.0	0.0	0.0	0	1.03	1.20	+.17	26.2	7.9	107	142	596	214	.440	2.25	63.7
11/8	21R	2616	7974	.084	.080	14:10	15:00	5	19.00	2.31	.704	Na_2S		0.52	.39	-.13	.32	.15	-.18	.93	.98	0.05	26.2	7.8	91	126	560	189	.440	2.25	63.7
11/13	27E	2749	837.9	.162	—	10:30	11:00	7	19.27	2.36	.719	None		1.12	1.25	+.13	.67	.67	0	.65	.59	0	24.4	7.9	104	124	620	167		2.6	72.6
11/13	27E	2749	837.9	.162	—	12:00	13:00	7	19.25	2.30	.701	$Zn SO_4$ 7.4		.98	1.15	+.17	0	0	0	1.38	1.24	-.14	25.0	7.9	74	109	560	153		2.3	65.1
11/13	27E	2749	837.9	.162	—	13:40	13:30	3	20.40	2.22	.677	None		.70	.70	0	—	—	—	1.26	.57	-.69	25.5	—	57	236	608	342		2.2	62.3
11/14	27D	1630	496.8	.0975	—	11:30	12:20	6	18.15	1.49	.454	Na_2S		1.57	2.13	+.56	—	—	—	.97	.50	-.47	26.0	7.8	73	185	552	260	.32	1.9	53.8
11/14	27D	1630	496.8	.0975	—	13:20	13:40	3	18.15	1.49	.454	Na_2S		7.0	6.7	-.3	—	—	—	—	—	—	—	—						1.9	53.8
11/14	27D	1630	496.8	.0975	—	12:30	12:50	3	18.15	1.49	.454	None		.43	1.53	+.9	—	—	—	.81	.49	-.32	25.0	7.7						1.9	53.8
11/14	27D	1630	496.8	.0975	—	13:50	19:40	6	18.15	1.49	.454	$Zn SO_4$ 197		.54	1.00	+.46	0	Tr	Tr	.87	.54	-.33	25.0	7.6	52	147	516	206		1.9	53.8
11/19	11C	1635	498.4	0.24	.231	10:50	12:10	9	13:27	2.03	.619	Na_2S		1.99	1.69	-.30	1.1	1.2	+.1	4.4	2.9	-1.5	23.9	8.2	45	149	444	195	.39	.49	13.9
11/19	11C	1635	498.4	0.24	.231	13:25	13:55	4	13:30	2.04	.622	$Zn SO_4$ 29.3		0	0	0	—	—	—	4.5	4.2	-.3	23.9	8.1	57	181	492	236	.31	.41	12.5
11/22	60F	3748	1142.4	.175	.176	10:55	11:10	4	9:10	7.65	2.33	Na_2S		.45	.50	+.05	.35	.35	0	.85	.51	-.34	24.4	8.1					.641	102	23.81
11/22	60F	3748	1142.4	.175	.176	11:15	11:40	6	9:20	7.50	2.29	Na_2S		.50	.43	-.07	.30	.18	-.12	.59	.48	-.11	24.4	7.9	88	226	724	304	.641	102	23.81
11/22	60F	3748	1142.4	.175	.176	13:10	13:35	6	9:20	7.50	2.29	$Zn SO_4$ 55		.07	.09	+.02	0	—	—	.85	.56	-.29	25.0	7.6	43	201	609	282	.630	99.6	23.07

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Los Angeles Co. San. Dist.
Sulfide Research Project

Summary Data Sheets
Build-up - Depletion Sites

Appendix B
Sheet No. 3
Revised 2/24/69

Date	Site	Length feet	Length Minutes	Slope Pipe %	Slope I.S. %	Hours From	Hours To	No. of Tests	Velocity Time	Velocity fps	Velocity m/sec	Feed Info Chemical	Feed Info Zn mg/l	Total Sulfide U.M. mg/l	Total Sulfide L.M. mg/l	Total Sulfide Δ S mg/l	Dis. Sulfide U.M. mg/l	Dis. Sulfide L.M. mg/l	Dis. Sulfide Δ S mg/l	Dis. Oxygen U.M. mg/l	Dis. Oxygen L.M. mg/l	Dis. Oxygen Δ D mg/l	Avg. Temp °C	Avg. pH	Comp BOD 1 day	Comp BOD 5 day	COD	EBOD	Flow d/D	Flow cfs	Flow g/sec
1968																															
11/27	18D	2901	884.2	.120	.113	10:30	11:30	6	35:49	1.34	.408	Na_2S		1.65	.43	-.22	–	–	–	3.6	1.57	-2.0	24.2	8.0		321		314		.65	18.4
11/27	18D	2901	884.2	.120	.113	1:00	1:50	4	38:55	1.25	.381	Na_2^+S		1.65	.79	-.82	1.0	.67	-.33	3.5	1.6	-1.9	25.0	7.8		160		224		.55	15.6
11/27	18D	2901	884.2	.120	.113	1:57	2:05	2		1.25	.381	None		.05	.15	+.10	–	–	–	3.5	1.9	-1.6	25.0	7.7		–				.55	15.6
11/27	18D	2901	884.2	.120	.113	2:10	3:00	5	41:00	1.18	.360	$Zn.SO_4 2.2$		.02	.08	+.06	–	–	–	3.1	2.3	-1.8	25.0	7.7		178		250		.55	15.6
12/4	18D	2901	884.2	.120	.113	2:15	12:25	8	41	1.20	.366	Na_2S		1.35	.56	-.79	.57	.23	-.34	3.8	1.5	-2.3	–	–		188		268		.58	16.4
12/4	18D	2901	884.2	.120	.113	1:40	2:40	8	41:15	1.16	.354	Na_2S Sc_3		0.0	0.04	+.04	–	0.0	0	9.9	1.9	-2.0	–	–		132		181		.53	15.0
12/5	18D	2901	884.2	.120	.113	11:30	12:30	7	39:50	1.39	.424	Na_2S		1.51	.66	-.85	0.90	0.43	-.47	3.4	1.4	-2.0	23.9	7.5	–	–	–	.247		.46	13.0
12/11	18D	2901	884.2	.120	.114	12:10	1:10	7	36:35	1.57	.482	Na_2S		.79	.44	-.35	.37	.28	-.05	4.1	2.1	-2.0	24.2	7.7	47	137	–		.254	.65	18.4
12/11	18D	2901	884.2	.120	.114	2:22	3:22	7	40:40	1.48	.451	Na_2S		1.7	.98	-.72	.78	.20	-.58	3.5	2.3	-1.2	24.4	7.7	40	167	–		.234	.55	15.6
12/12	18D	2901	884.2	.120	.114	10:40	11:40	7		1.67	.509	Na_2S		1.67	1.48	-.19	.68	.52	-.16	3.7	1.8	-1.9	24.4	8.00	23	119				.75	21.2
12/12	18D	2901	884.2	.120	.115	1:40	2:40	7	32:20	1.50	.457	Na_2S		1.4	.84	-.56	.67	.3	-.37	4.6	4.65	0	23.9	8.05	–	–				.60	17.0
1969																															
1/30	27SS	2749	837.9	.162	–	11:10	11:30	5	23:15	1.97	.600	None		.29	.51	+.12	.15	.20	+.05	1.04	0.5	-.54	20.0	8.1	–		–		.24	3.1	87.8
1/30	27SS	2749	837.9	.162	–	12:30	1:20	7	23:15	1.97	.600	$Zn.SO_4 6.8$		.44	.89	+.45	0	0	0	1.2	0.6	-.60	20.0	8.1	–	247	–		.24	2.6	73.6
2/4	27SS	2749	837.9	.162	–	10:45	11:45	7	23:20	1.96	.597	Na_2S		1.77	2.31	+.54	1.17	1.0	-.17	1.15	.64	-.51	21.1	8.4					.24	3.1	87.8
2/4	27SS	2749	837.9	.162	–	12:40	13:10	7	23:20	1.96	.597	None		.93	.59	+.16	Tr.	0.2	+0.2	1.09	.55	-.49	21.1	–					–	2.6	73.6
2/4	27SS	2749	837.9	.162	–	13:32	14:30	7	24:50	1.85	.564	$Zn.SO_4 8.5$		.81	1.31	+.50	0	0.1	+.1	1.04	.41	-.93	21.1	8.1					–	2.5	70.8
2/4	27SS	2749	837.9	.162	–	14:35	15:00	5	24:50	1.85	.564	$Zn.SO_4 25.5$		.99	1.06	+.22	0	.0	0	1.15	1.40	+.25	21.1	8.1					–	2.5	70.8
1/16	18D	2901	884.2	.120	.114																										
1/16	18D	2901	884.2	.120	.114																										
1/16	18D	2901	884.2	.120	.114																										
2/14	24D	5873	1796.2	.0536	–	11:10	12:10	6	49:03	2.00	.610	Na_2S		1.64	1.13	+.09	.5	.45	-.05	2.5	.95	-1.55							.675	239	67.4
2/14	24B	5873	1796.2	.0536	–	12:50	13:20	7	51:00	1.92	.582	None		.21	.61	+.40	–	.17	–	2.1	1.0	-1.1							.655	230	65.1
2/14	24B	5873	1796.2	.0536	–	13:40	14:40	7	53:15	1.85	.564	$Zn.SO_4 5.7$		.23	.97	+.74	–	.07		2.1	1.6	-.5	21.1						.660	2.25	63.7
2/14	24B	5873	1796.2	.0536	–	15:38	19:53	4	—	–		Zn	11.4	–	.95	+.72					2.0	0	21.1						.660	—	
2/27	21GR	2616																													
2/27	21GR	2616																													
3/6	6C	5.12																													
3/6	6B	5.12																													
3/6	6B	5.12																													
3/11	24B	4137																													
3/11	24D	4137																													
3/11	24C	4137																													
3/11	24B	4137																													

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APPENDIX C-1

Field Test Procedure for Shock Dosing with NaOH for Sulfide Control

Purpose: To document some currently-held opinions about the size and duration of shock doses of NaOH for sulfide control in gravity sewers.

Site: With help of sulfide testing crew, select a spot where regular and frequent NaOH shock dosing is currently required. Other required characteristics are:

1) Accessibility to Compton yard to facilitate daily checking without excessive time loss.
2) Preferable pipe size 24" or less.
3) Sulfide production should occur in a definite definable reach of sewer.
4) May be a siphon or gravity reach.

Plan: First, hold time of application of dose constant and add varying amounts of NaOH and record recovery time of the slimes. Next, hold constant dosing rate and vary the time over which the dose is applied, and measure recovery time.

At the Test Site Measure: T.S. and D.S. one time each day for one week before shock dose, and after the shock dose, for as long as it takes for sulfide generation to return.

At the Feed M.H. during Time of NaOH Dose Record:

Time of Start of Dump

Time of Finish of Dump

Gallons dumped

Analyse N aOH Strength in Solution

At a Test Spot at Downstream End of the Test Reach

--Install PB slab flume and record Q (rate of flow) at time of the dump

--Take samples for alkalinity titration

--Measure time pH rises above 9.0 and returns to below a pH of 9.0.

Dosing Regimen: After discussion with sulfide test crew decide on an initial dose that corresponds to the amount the sulfide crew feels is enough for effective control in this situation. This will probably be 1000 or 2000 gallons discharged over 25 minutes.

After that initial dose (I), successive doses might be one-half I over 25 minutes, one-fourth I over 25 minutes, etc., until a markedly less effective dosing level has been reached.

From the data taken on the above runs determine the concentration of NaOH used on a minimum effective dose. Using this information a dosing level for the second set of tests would be set, say, X ppm. Then, we would dose at X ppm for 10 minutes, 20 minutes, 30 minutes, and 40 minutes with sulfide recovery time noted in between each dose.

APPENDIX C-2

Proposed Bottle Tests of Effect of Added Sludge on Sulfide Conditions in an Outfall Sewer

Purpose: To determine the extent to which the addition of various waste sludges to a sewage flow will increase its sulfide build-up potential.

Note: Bottle tests are preliminary to later tests in sewers.

Types of Sludges:

1) Raw Primary
2) Waste Activated Sludge
3) Waste Trickling Filter Humus *
4) Digested Sludge from Activated Sludge Plant

* Should be included to give results broad enough applicability.

General Plan: Prepare multiple, one ounce, completely filled bottles of sewage plus 1% of sludge. Incubate these bottles and take off two bottles per day for 10 days for determination of total sulfide.

Preconditioning: Bottle tests always have a time lag due to absence of the conditioned slime cultures that sewers have on the submerged sewer wall. This lag could perhaps be minimized by a preconditioning period and the introduction of a culture encouraging surface in the bottle. Procedure would be as follows:

1) Add test solutions of sewage with 1% added sludge to all the bottles to be used in the test.
2) Add 1/4 inch layer of coarse filter sand to each bottle.
3) Incubate mixtures for five days (ambient room temperature)
4) Pour off the liquid after gentle shaking to re-suspend the loose sludge particles. Leave the sand behind in the bottle.
5) Refill the bottles with the same mixture as was used for preconditioning.
6) Incubate these bottles at 25°C taking off two bottles each day for ten days for sulfide production.

Test Solutions:

1) Sewage only + 500 mg/liter Na_2SO_4
2) 800 ml sewage + 8 ml raw primary sludge + 499 mg Na_2SO_4
3) " " " " W.A.S. " "
4) " " " " W.T.F.H. " "
5) " " " " Digested Sludge " "

APPENDIX C-3

Effect of Added Sludge on Sulfide Build-up Potential in an Outfall Sewer

Warburg BOD Tests

Purpose: The general purpose is to determine the effect of various waste sludge additions to a sewage flow on its sulfide build-up potential.

Measurement of the rate at which the oxygen demand of the mixtures is exerted may help to predict the tendency of various sludge additions to increase sulfide build-up potential.

Types of Sludges:

1) Raw Primary
2) Waste Activated Sludge
3) Waste Trickling Filter Humus
4) Digested Sludge from an Activated Sludge Plant

Test Solutions:

Series I:

1) Sewage only
2) 495 ml sewage plus 5 ml of Raw Primary Sludge
3) " " " " " " Waste Activated Sludge
4) " " " " " " Trickling Filter Humus
5) " " " " " " Digested Sludge

Series II:

1) 490 ml sewage plus 10 ml Raw Primary Sludge
2) 490 " " " 10 ml Waste Activated Sludge
3) 490 " " " 10 ml Digested Sludge
4) 490 " " " 10 ml Digested Sludge

Preconditioning: It seems important to precondition the bottles to develop therein a bacterial population that is able to utilize the sludge sewage mixtures to be used. Proposed procedure:

1) Add test solution to the Warburg bottles to be used in the test.
2) Add a 1/4 inch layer of coarse filter sand to each bottle.
3) Incubate the sample for five days at ambient room temperatures.
4) Pour off the liquid after gentle shaking to re-suspend the loose sludge particles. Leave the sand behind in the bottle.
5) Refill each bottle with the same mixture as used for the pre-conditioning.
6) Proceed with the Warburg Oxygen Demand tests.